REPORT No. 419

WIND-TUNNEL RESEARCH COMPARING LATERAL CONTROL DEVICES, PARTICULARLY AT HIGH ANGLES OF ATTACK

I—ORDINARY AILERONS ON RECTANGULAR WINGS

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SUMMARY

This report is the first of a series in which it is intended to compare the relative merits of all ordinary and some special forms of ailerons and other lateral control devices in regard to their effect on lateral controllability, lateral stability, and airplane performance. The comparisons are based on wind-tunnel test data, all the control devices being fitted to model wings having the same span, area, and airfoil section, and being subjected to the same series of force and rotation tests.

In this particular report the results are given for ordinary ailerons of three different sizes. The medium-sized ailerons, which with equal upward and downward deflection are used as a standard for comparison, had a chord 25 per cent of the wing chord and a span 40 per cent of the semispan of the wing. Of the other two sizes, one was long and narrow and the other short and wide. The results are given for five different aileron movements: One with equal up-and-down deflection, one with average and one with extreme differential motion, one with upward deflection only, and one with the ailerons arranged to float with respect to the wing.

The results showed that although the ailerons of medium size with either the equal up-and-down or the commonly used differential motions gave very unsatisfactory control above the stall, satisfactory control was obtained with the short, wide ailerons with upward deflection only, and was closely approached by the same ailerons with extreme differential motion. The short, wide and the medium ailerons with upward deflection only also gave powerful yawing moments which at all angles of attack would aid the rolling, although with small deflections above the stall slight adverse yawing moments occurred. The only ailerons which gave no adverse yawing moments at any deflection or angle of attack were the short, wide ones arranged to float.

INTRODUCTION

GENERAL

One of the most promising methods of increasing the safety of airplanes is the provision of adequate lateral control and lateral stability at the low speeds and high angles of attack. Conventional ailerons as used at the present time are satisfactory for the usual flight range up to angles of attack just below that for maximum-lift coefficient (the stall), but they are very poor at the angles above the stall. This condition is one of the greatest dangers in present-day flying, and is often the cause of airplanes falling out of control and into spins. At the relatively low angles of attack below the stall the flight-path angle in a glide is usually not as steep as is desirable for a short approach to a landing. The flight path can be made steeper by flying at a higher angle of attack; hence it is desirable to fly and to have good lateral control and stability at the higher angles of attack.

Many devices, such as slots and floating wing-tip ailerons, have been devised for improving the lateral control at these high angles. While most of these devices have previously been tested in individual isolated cases, it is not possible to get a good comparison between them because the individual tests were made under different conditions in several different wind tunnels or in isolated flight tests, and with various degrees of completeness.

As part of a general investigation of safety in flight the N. A. C. A. has undertaken a series of tests in which it is hoped to compare all types of lateral control devices which have been satisfactorily used or which show reasonable promise of being effective. It is planned first to test the various types of ailerons and lateral control devices on rectangular wings of aspect ratio 6. Later the best controls are to be tested on wings of different shape. Throughout the entire investigation all the devices are being subjected to the same series of wind-tunnel tests which, it is hoped, include all the factors directly connected with lateral control and lateral stability that can be satisfactorily handled in a routine manner in a wind tunnel. These tests cover the relative merit of the various control devices in regard to lateral controllability, lateral stability, and general usefulness. They include regular 6-component force tests with the ailerons, or other control devices, both neutral and deflected various amounts, rotation tests in which the model is rotated about the wind-tunnel axis and the rolling moment is measured, and free rotation tests showing the range and rate of autorotation. Because of the large effect of yaw on the stability in roll, the tests are made not only with an angle of yaw of 0°, but also with one of 20°, which represents the conditions in a fairly severe sideslip.

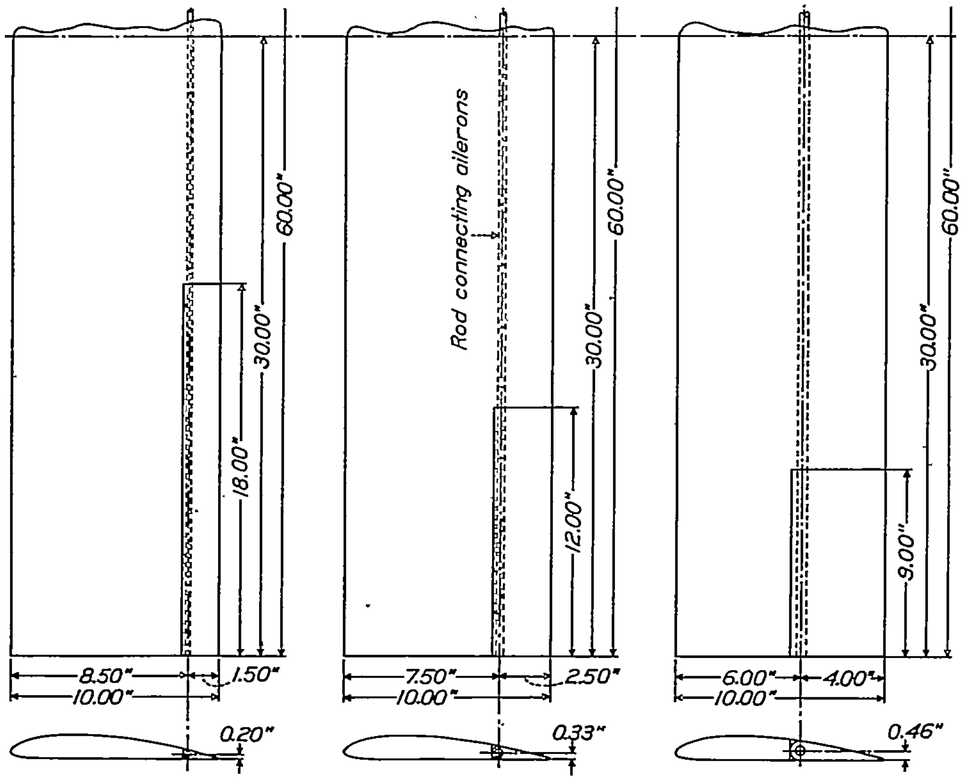
Throughout the entire investigation it is intended in so far as possible to use model wings having a span of 60 inches, an aspect ratio of 6, and the Clark Y airfoil section. The first wing has ailerons of medium dimensions (25 per cent wing chord by 40 per cent semispan) representing the average found from a number of conventional airplanes and, with the average maximum deflection of ±25°, will be taken as the standard with which all the others will be compared. Since it has been found through simple flight tests made for the purpose (reference 1) that ailerons of this size and form will ordinarily give satisfactory lateral control just below the stall, all of the other ailerons and control devices will be designed to give approximately the same amount of control under those conditions.

Because of the large number of factors involved in this investigation, a clear and complete comparison of the various devices is difficult. To facilitate this comparison a number of standard criterions will be used throughout the entire investigation. All the tests will be made in the 7 by 10 foot wind tunnel of the National Advisory Committee for Aeronautics. (Reference 2.)

PRESENT PORTION OF INVESTIGATION

This particular report describes the tests on three rectangular model wings with ordinary ailerons of different sizes. Tests of this same general nature have been previously made at the Bureau of Standards. (References 3, 4, and 5.) They do not, however, include all of the factors included in the present investigation.

In addition to the first wing with medium-sized ailerons, which will be used as the standard of comparison, a second was provided with long, narrow ailerons and a third with short, wide ones, both proportioned to give approximately the same rolling moments as the medium ailerons, with the same deflection at angles of attack below the stall. The results are given for several different kinds of aileron movement; namely, equal up-and-down deflection, two different differential movements, upward movement only, and one with the ailerons arranged to float. Control forces have been computed from the Bureau of Standards tests (reference 5) and are given with the present results.



Stations and ordinates in per cent of chord

Station	0.00	1.25	2.50	5.00	7.50	10	15	20	30	40	50	60	70	80	90	95	100
Upper	3.50	5.45	6.50	7.90	8.85	9.60	10.69	11.36	11.70	11.40	10.52	9.15	7.35	5.22	2.80	1.49	0.12
Lower	3.50	1.93	1.47	0.93	0.63	0.42	0.15	0.03	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

FIGURE 1.—Details of ailerons on Clark Y wings

APPARATUS

Model wings.—The model wings were made of laminated mahogany and the ordinates were held accurate in construction to within ±0.005 inch of those specified. The sizes of the ailerons are shown on Figure 1. The medium ones are 25 per cent of the wing chord by 40 per cent of the semispan. The long, narrow ones are 15 per cent of the chord by 60 per cent of the semispan and the short, wide ones are 40 per cent of the chord by 30 per cent of the semispan.

The ailerons, when allowed to float, were both rigidly mounted on a shaft supported in bearings in the wing. For the floating condition they were constructed so as to balance statically about the hinge axis, by means of a balsa-wood trailing edge and a brass nose piece.

Wind tunnel.—The 7 by 10 foot wind tunnel has an open jet and a single closed return passage. The tunnel, the balances, and auxiliary apparatus are described in detail in reference 2.

For ordinary force tests the model is mounted on a vertical spindle attached to a rectangular frame surrounding the test section of the air stream. The balances are arranged to measure all six components of the aerodynamic forces and moments about the tunnel axis directly in coefficient form. For the tests with floating ailerons an optical sighting device is used to measure the angle δ_{A_F}, at which the ailerons float.

For both the free-autorotation and the forced-rotation tests the models are mounted on an apparatus which replaces the force-test model support. The apparatus consists essentially of a shielded shaft mounted on ball bearings at the center line of the air stream. This shaft is either allowed to rotate freely or is driven through reduction gearing by an electric motor. The rolling moment due to rolling is measured directly in coefficient form on the regular rolling-moment balance.

TESTS

All the tests were made at a dynamic pressure of 16.37 pounds per square foot, corresponding to an air speed of 80 miles per hour at standard sea-level atmospheric conditions. The Reynolds Number was 609,000.

Aileron movements.—Four different aileron movements were investigated with the rigid ailerons. One of these was with equal up-and-down deflection, one with average and one with extreme differential movement, and one with upward deflection only. If tested individually the several different movements would have required a very large number of tests. It seemed that a great many of these could be eliminated by testing the ailerons individually with up-and-down deflection separately, and then adding the results to get the combined effect. Although theory indicates that this is not a rigorously accurate procedure, because of the different wing-load distribution, preliminary tests were made which showed good agreement within the accuracy of the investigation. The final tests were made with the ailerons deflected equal and opposite amounts, and also with one aileron at a time deflected first upward and then downward. The moments for the differential deflections were then computed from the results of the tests with one aileron deflected at a time.

The medium differential arrangement was taken from a study of several conventional airplanes, the maximum aileron deflections averaging 35° up and 15° down. The extreme differential movement was selected to give as nearly as possible the up-only movement which seemed desirable from previous tests. With the assumed maximum deflection for this differential movement one aileron is 50° up and the other is 7° down. Table I gives the relative deflections of the right and left ailerons throughout the range of displacement with the two differential arrangements. These are illustrated in Figure 2, which also shows the assumed linkage systems used for making control-force computations for all the aileron movements.

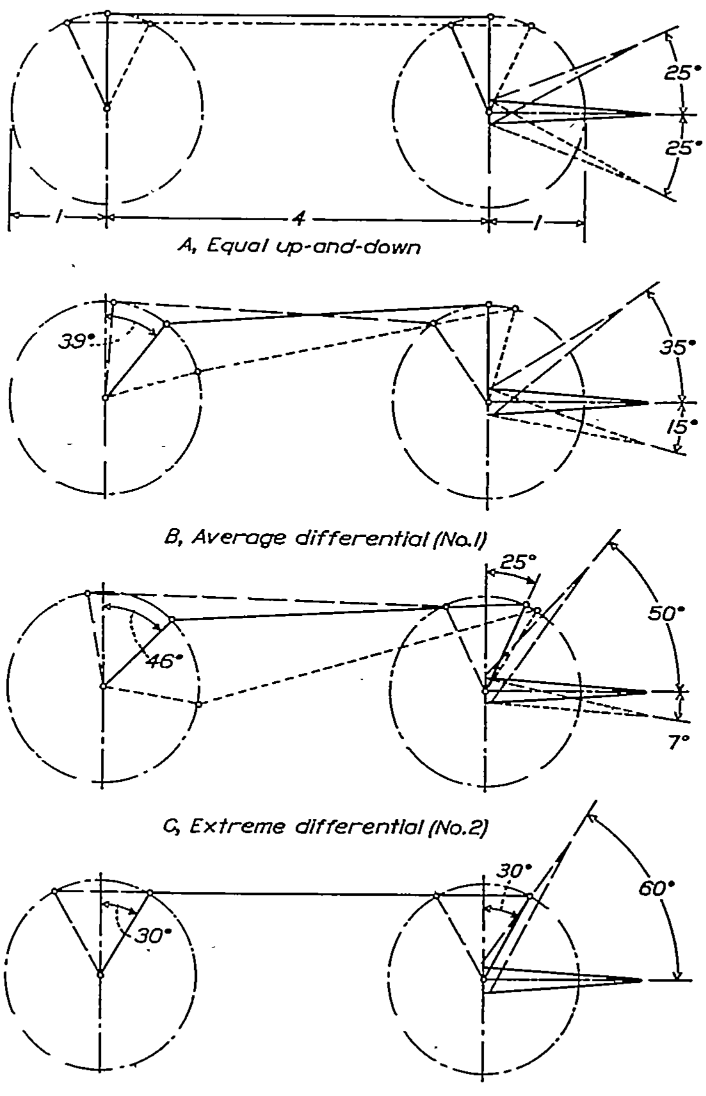


FIGURE 2.—Aileron linkage systems—assumed maximum deflections

TABLE I

ASSUMED DIFFERENTIAL AILERON ARRANGEMENTS

Average differential (No. 1)			Extreme differential (No. 2)		
Drive crank angle [a] from 39°	Aileron deflection [b]		Drive crank angle [a] from 46°	Aileron deflection [c]	
	Up	Down		Up	Down
0°	0.0°	0.0°	0°	0.0°	0.0°
10°	8.0°	7.0°	10°	7.5°	5.5°
20°	17.0°	12.0°	20°	16.0°	10.4°
30°	28.0°	14.8°	30°	25.5°	13.6°
40°	40.0°	15.2°	40°	35.5°	13.1°
50°	60.0°	13.5°	50°	55.7°	3.3°

[a] Drive crank initial angle from vertical. (See fig. 2.)
[b] Aileron crank angle 90° to aileron chord.
[c] Aileron crank angle 65° to aileron chord.

Force tests.—Complete series of force and moment tests were made on each wing model with the ailerons neutral and with the ailerons deflected various amounts, both while attached rigidly to the wing and while floating with respect to the wing. The aileron deflections tested in the fixed condition were:

(a) Left aileron deflected downward and right deflected upward 0°, 10°, 20°, 30°, 40°, 50°.

(b) Left aileron deflected downward 0°, 10°, 20°, 30°, 40°; right aileron 0°.

(c) Right aileron deflected upward 0°, 10°, 20°, 30°, 40°, 60°, 80°; left aileron 0°.

When floating with reference to the wing, the total deflections of one aileron with respect to the other, left aileron down and right up, were 0°, 20°, 40°, 60°, 80°, 100°.

The angle-of-attack range for the force tests with the ailerons neutral was from $-10°$ to $+60°$, and with the ailerons deflected, from 0° to 40°. A complete series of tests was made at both 0° yaw and $-20°$ yaw. In the yawed tests the ailerons were deflected in a manner to oppose the rolling moment due to the yaw of the wing.

Rotation tests.—A series of free autorotation tests was made on each wing model with the ailerons neutral, first in the fixed condition and then floating. The reduction gearing was disengaged so that the model could rotate freely about the tunnel axis. Starting well below the stall, the angle of attack was increased in small steps until the model would just start to rotate when given a slight impulse by hand. This angle of attack denoted the starting point of autorotation. The whole range of autorotation was then covered and the angles of attack and rates of rotation were noted. These tests were made only at 0° yaw because the rotational velocities became excessively high at 20° yaw, with possibilities of damage to the testing apparatus.

A series of rotation tests to obtain the coefficient of the rolling moment due to rolling was made on each of the wings with the ailerons neutral, both locked and floating. The angle-of-attack range was from 0° to 40°, and the tests were made at both 0° and $-20°$ yaw.

Rotations in both clockwise (+) and counterclockwise (−) directions were made at a rate representing the maximum rolling motion likely to occur in flight in gusty air when the pilot is attempting to hold the airplane level. This maximum rate of rolling was found by special test flights to be such that the coefficient of rotation has the value

$$\frac{p'b}{2V}=0.05$$

where p is the angular velocity in radians per second, b is the span of the wing, and V is the velocity of advance.

Accuracy.—The dynamic pressure was maintained constant to within ±0.25 per cent. The angle of attack was accurate to within ±0.1°, and the angle of yaw to ±0.2°. The minimum-drag values, which are the averages of several readings, are thought to be accurate within ±3 per cent. The lift may be relied upon to within ±1 per cent and the rolling and yawing moment coefficients, in general, to within ±3 per cent.

The foregoing accuracy applies to angles of attack up to and through the stall and also to angles above 25°. At some of the angles between 20° and 25°, however, critical flow conditions apparently exist in which burbling does not occur with exact symmetry over the wing. This dissymmetry sometimes causes two or more different values of the rolling and yawing moments to be obtained. The results are consequently rather unreliable for the angles of attack between 20° and 25°. The same turbulent condition probably exists also in flight at the corresponding angles and it can not be certain there either that the same control moments will be obtained repeatedly within the above range of angles of attack.

Oscillation of floating ailerons.—Although all the ailerons were constructed in such a manner as to have static inertia balance about their hinge axes, when allowed to float they fluctuated or wavered slightly at certain speeds and deflection settings at certain angles of attack above the stall. The oscillation was not violent and in most cases was not steady, apparently being associated with the turbulent air flow over the wings. However, it is a condition which might be undesirable in flight at certain angles of attack above the stall.

RESULTS

Coefficients.—The force-test results are given in the form of absolute coefficients of lift and drag and of the rolling and yawing moments:

$$C_L=\frac{\text{lift}}{q\,S}$$

$$C_D=\frac{\text{drag}}{q\,S}$$

$$C_l'=\frac{\text{rolling moment}}{q\,b\,S}$$

$$C_n'=\frac{\text{yawing moment}}{q\,b\,S}$$

where S is the total wing area, b is the wing span, and q is the dynamic pressure.

The coefficients as given above are obtained directly from the balance and refer to the wind (or tunnel) axes. In special cases in the discussion where the moments are used with reference to body axes, the coefficients are not primed. Thus, the symbols for the rolling and yawing moment coefficients about body axes are C_l and C_n.

The results of the rotation tests are given, also about the wind axes, in terms of the rotation coefficient $\frac{p'b}{2V}$ and an absolute coefficient of rolling moment due to rolling,

$$C_\lambda=\frac{\lambda}{qbS}$$

where λ is the rolling moment measured while the wing is rolling, and the other factors have the usual significance.

Tables.—Tables II and III list the coefficients of C_L, C_D, C_l', and C_n' for 0° and −20° yaw, respectively, obtained from the force tests on the wing with medium-sized ailerons (25 per cent chord by 40 per cent semispan) having the ailerons both neutral and deflected and in both the locked and floating conditions. The angles at which the left aileron floated with respect to the wing chord are also tabulated, the negative sign denoting aileron up and the positive sign denoting aileron down. Table IV gives the values of C_λ at $\frac{p'b}{2V}=0.05$, and values of $\frac{p'b}{2V}$ over the free-rotation range for the same wing at 0° yaw with the ailerons neutral in both the locked and floating conditions. Table V lists the values of C_λ at $\frac{p'b}{2V}=0.05$ obtained at −20° yaw. Tables VI to IX, inclusive, give the results corresponding to the above conditions for the wing with long, narrow ailerons (15 per cent chord by 60 per cent semispan); and Tables X to XIII, inclusive, list the results for the wing with short, wide ailerons (40 per cent chord by 30 per cent semispan).

Figures.—The test results are also given in the form of curves for the wing with medium-sized ailerons, these ailerons representing the standard of comparison for the entire investigation. The curves for the other ailerons are not given because the shapes of the corresponding curves for the three wings are roughly similar and the essential results are all compared in a table of criterions.

Figure 3 gives the curves of the lift and drag coefficients against angle of attack for the wing with ailerons neutral, both locked and floating, and for both 0° and −20° yaw. Rolling and yawing moment coefficients for the ailerons locked with equal up-and-down deflection and 0° yaw are plotted against angle of attack in Figure 4. Figure 5 gives the rolling and yawing moment coefficients for ailerons locked with the right aileron neutral and the left deflected down different amounts at 0° yaw. Similar coefficients with the left aileron neutral and the right deflected up different amounts at 0° yaw are given in Figure 6. Figures 7, 8, and 9 give the rolling and yawing moment coefficients for the corresponding conditions, but at −20° yaw. Rolling and yawing moment coefficients for the ailerons floating, right aileron up and left down various amounts, are given against angles of attack for 0° yaw in Figure 10, and for −20° yaw in Figure 11.

Curves of free autorotation, $\frac{p'b}{2V}$ against angle of attack, for the wings with ailerons neutral, both in the locked and floating conditions, are given for 0° yaw in Figure 12. Coefficients of rolling moment due to rolling at $\frac{p'b}{2V}=0.05$ are given in Figure 13 for the wing with ailerons neutral, both locked and floating at 0° yaw, and in Figure 14 for −20° yaw.

CRITERIONS FOR COMPARING RELATIVE MERIT OF AILERONS

A number of criterions are used for comparing the effect of the various ailerons on the general airplane performance, on the lateral controllability, and on the

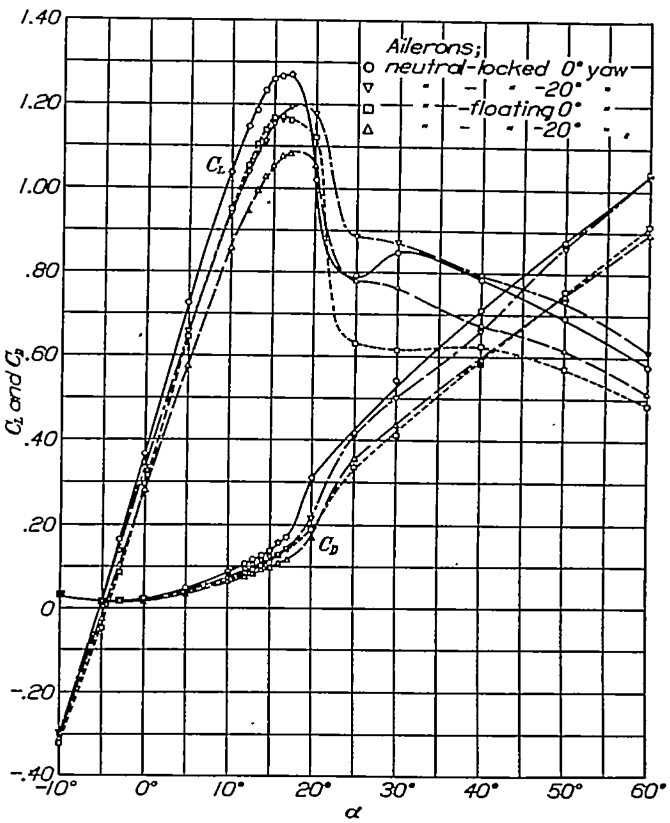


FIGURE 3.—Lift and drag coefficients; 25 per cent chord ailerons neutral; 0° and −20° yaw

lateral stability. These are explained below and the values are listed in Table XIV for the 15 aileron combinations tested.

GENERAL PERFORMANCE

To compare the relative merit of the ailerons in regard to their effect on airplane performance characteristics, three simple criterions are used.

Wing area required for desired landing speed.—The first criterion is the maximum lift coefficient $C_{L_{max}}$

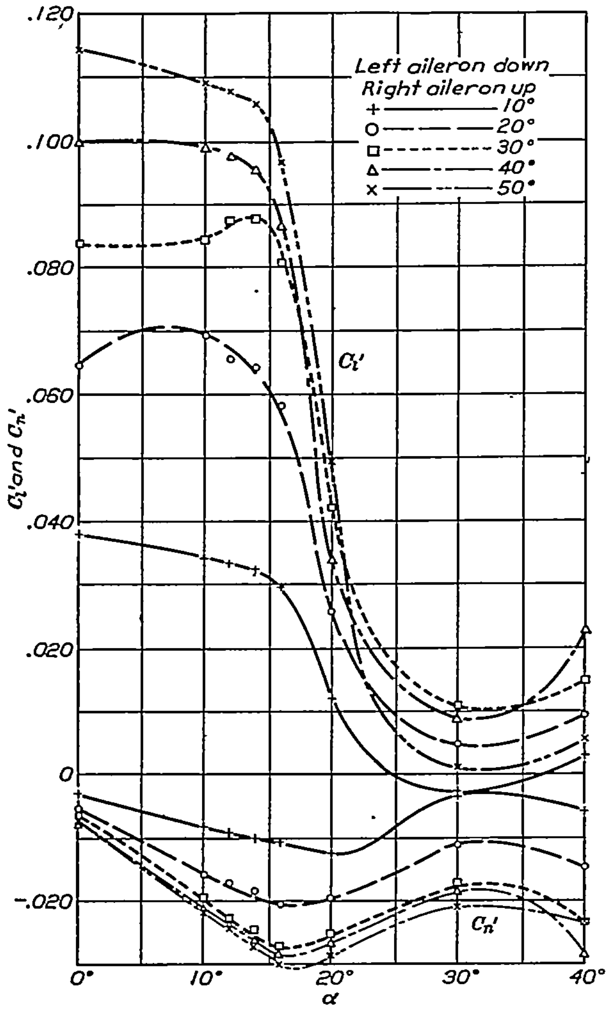


FIGURE 4.—Rolling and yawing moment coefficients due to 25 per cent chord aileron up and down. Ailerons locked; 0° yaw

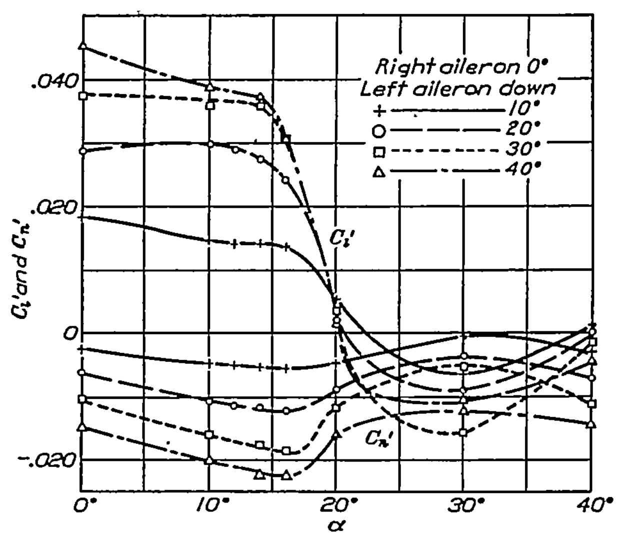


FIGURE 5.—Rolling and yawing moment coefficients due to 25 per cent chord aileron down. Ailerons locked; 0° yaw

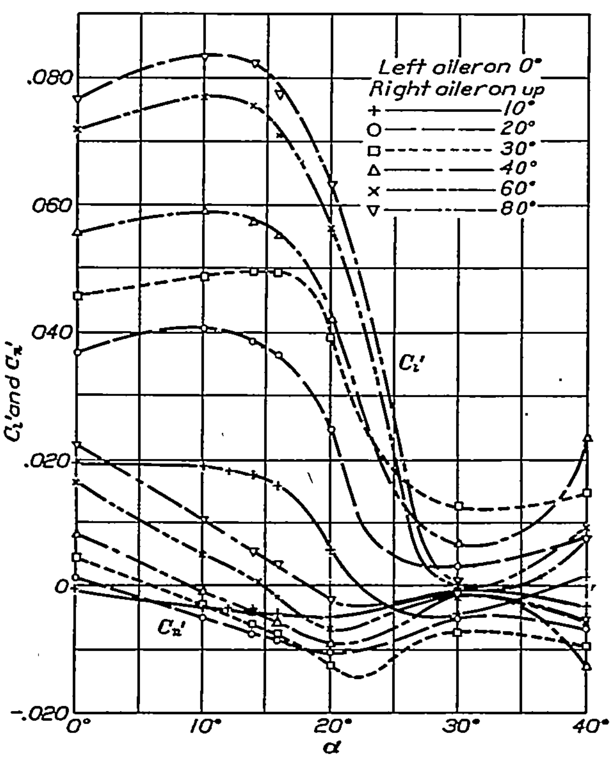


FIGURE 6.—Rolling and yawing moment coefficients due to 25 per cent chord aileron up. Ailerons locked; 0° yaw

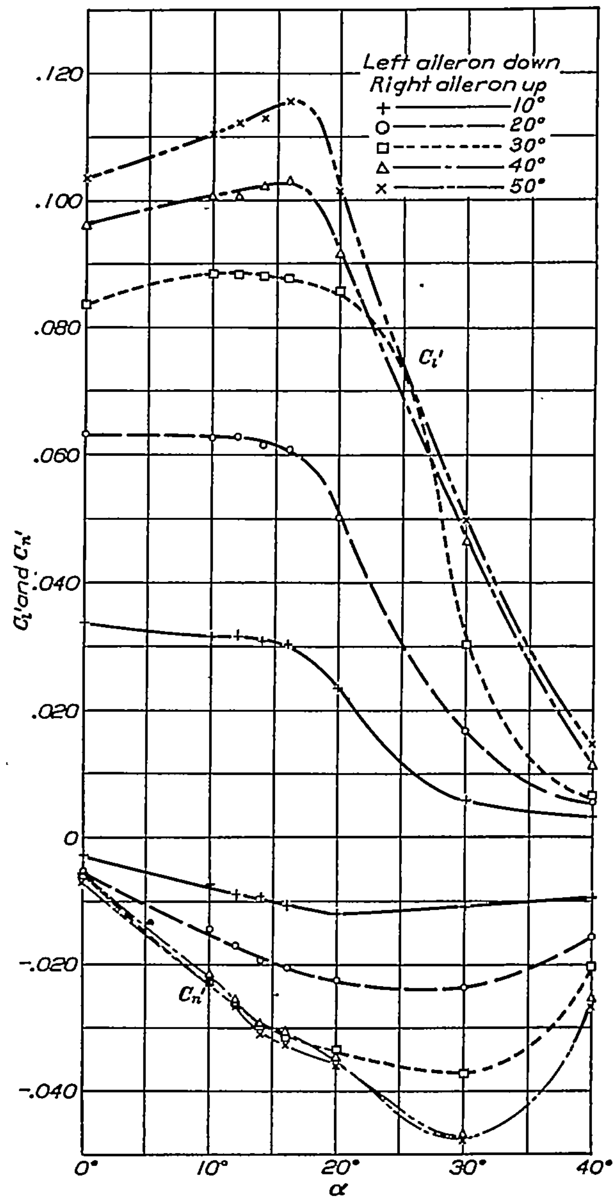


FIGURE 7.—Rolling and yawing moment coefficients due to 25 per cent chord ailerons up and down. Ailerons locked; −20° yaw

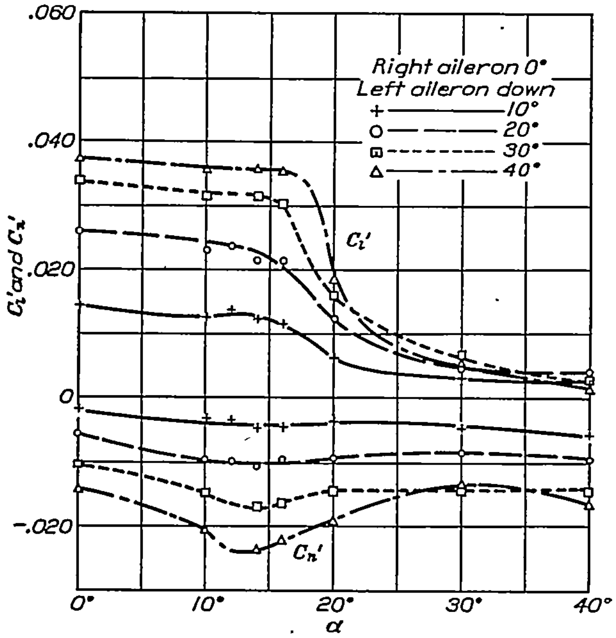


FIGURE 8.—Rolling and yawing moment coefficients due to 25 per cent chord aileron down. Ailerons locked; −20° yaw

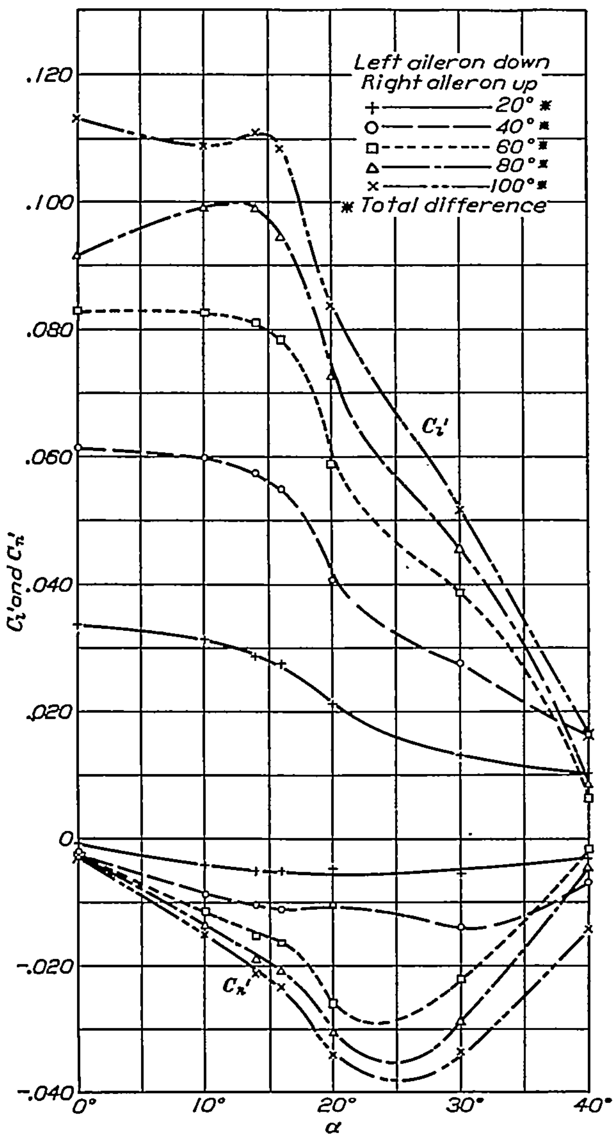


FIGURE 11.—Rolling and yawing moment coefficients due to 25 per cent chord ailerons up and down. Ailerons floating; −20° yaw

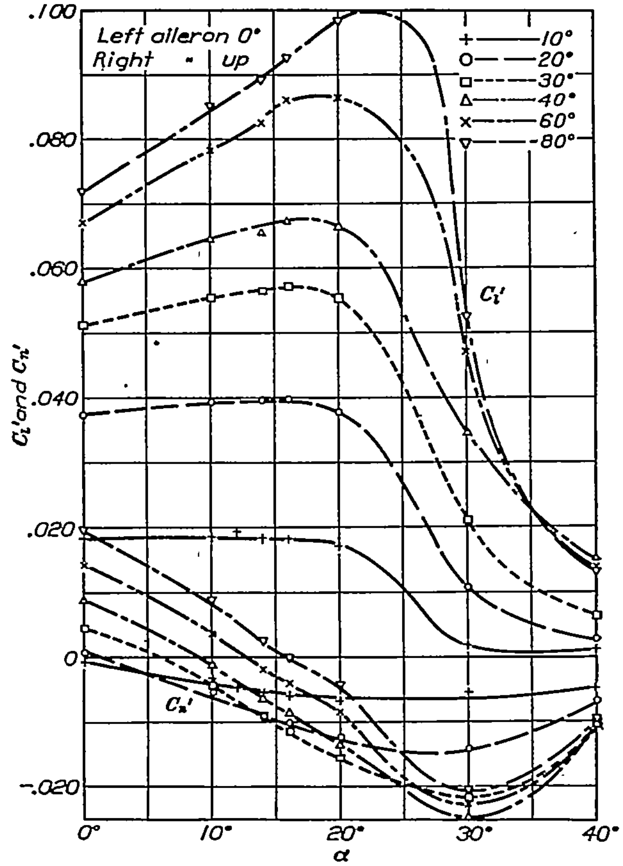


FIGURE 9.—Rolling and yawing moment coefficients due to 25 per cent chord aileron up. Ailerons locked; −20° yaw

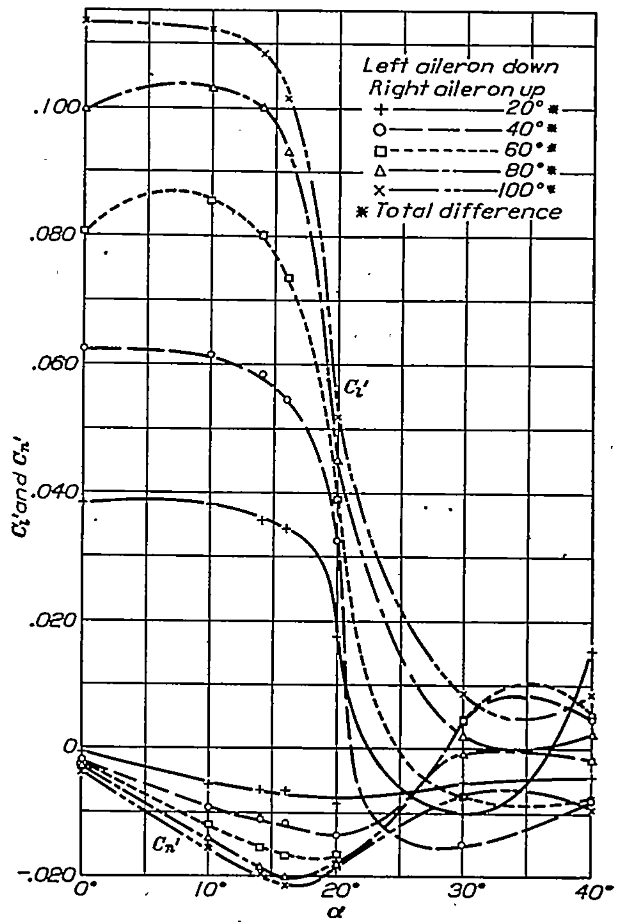


FIGURE 10.—Rolling and yawing moment coefficients due to 25 per cent chord ailerons up and down. Ailerons floating; 0° yaw

which is used as an indication of the wing area required for the desired landing speed.

Speed range.—The second is the ratio $\frac{C_{L_{max}}}{C_{D_{min}}}$ which is an indication of the speed range and which, for a given minimum speed, shows the suitability of the wing for high speed.

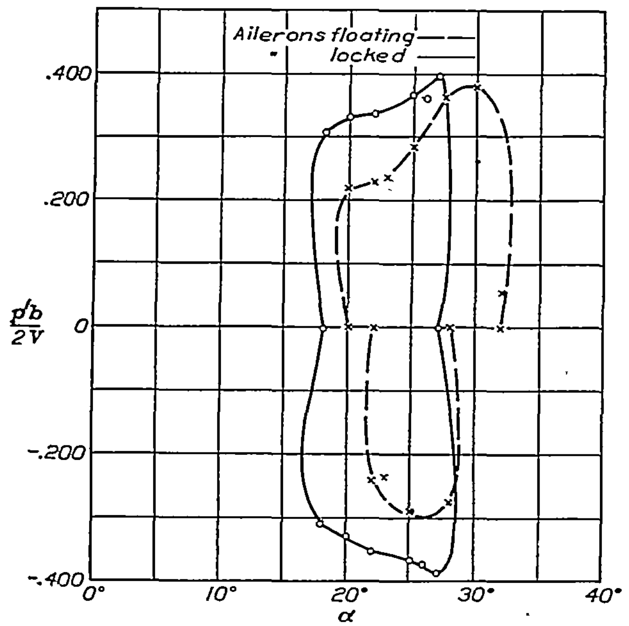


FIGURE 12.—Effect of floating 25 per cent chord ailerons on stable autorotation. Ailerons neutral; 0° yaw

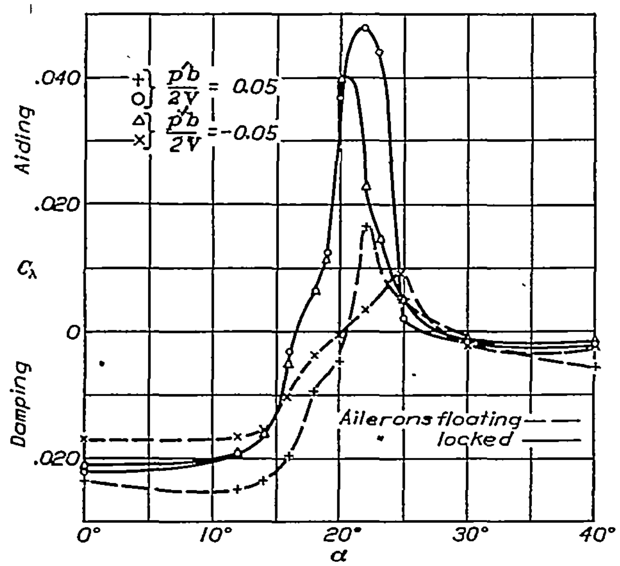


FIGURE 13.—Effect of floating 25 per cent chord ailerons on rolling-moment coefficient due to rolling at $\frac{p'b}{2V}$=0.05. Ailerons neutral; 0° yaw

Rate of climb.—The third general performance criterion, which is an indication of relative merit in climbing flight, is the ratio L/D taken at a value of the lift coefficient $C_L=0.70$. In a series of performance computations made for airplanes with a number of different wing loadings and power loadings, and with both plain and slotted wings, this criterion was found to be satisfactory throughout the entire range.

LATERAL CONTROLLABILITY

Rolling criterion.—The rolling-moment coefficient accompanying maximum aileron deflection could be used as a simple criterion of the lateral controllability, but it does not include all the factors involved and it is not independent of the air speed nor the angle of attack. A criterion is desired which expresses the ability to roll an airplane quickly a slight amount while attempting a smooth gliding course in gusty air, particularly at the angles of attack required for landing. This requirement is different from that of good maneuverability in that maneuverability depends mainly on

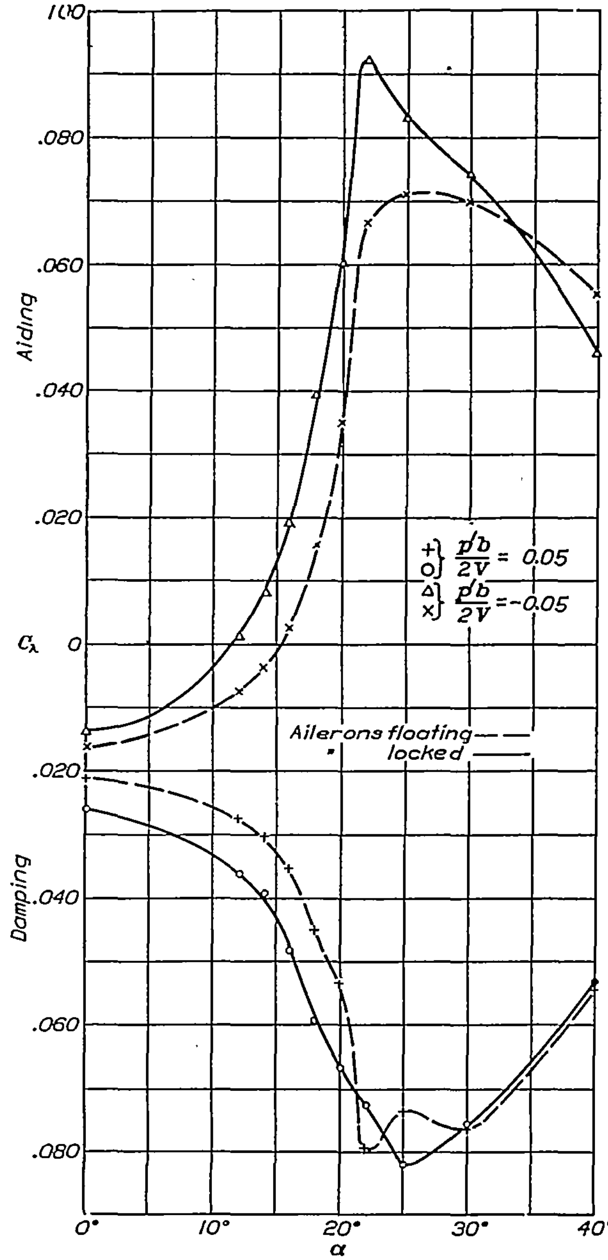


FIGURE 14.—Effect of floating 25 per cent chord ailerons on rolling-moment coefficient while rolling at $\frac{p'b}{2V}$=0.05. Ailerons neutral; −20° yaw

the rate of roll obtained through large angles, while the controllability as used here depends on the acceleration with which the rolling is initiated. This acceleration exists throughout a displacement in roll of 5° to 20°, depending on the type of airplane, after which the rate of roll is approximately constant. (References 6, 7, and 8.) The acceleration obtained at the start has therefore more effect on the controllability than has the final rate of roll.

Considering these points, a criterion of lateral controllability has been chosen to represent the tangential acceleration at the wing tip for a given airplane regardless of the speed of advance. This acceleration is dependent upon the mass moment of inertia of the whole airplane about its longitudinal, or X axis, as well as upon the rolling moment due to the ailerons. The mass moment of inertia is, of course, not available for use in a general criterion, but it is almost entirely due to the wing, and if a constant weight per unit area is assumed for the wing structure, the area moment of inertia of the wing about the longitudinal axis can be used with reasonable accuracy. This method then takes into account the plan form of the wing.

A rolling criterion $R\,C$ filling the above requirements may be expressed by the formula

$$R\,C=\frac{C_l\,S\,b^2}{12\,C_L\,I_x}$$

where C_l is the coefficient of rolling moment due to ailerons with respect to the body axis (which axis for the wing alone is taken as the midspan chord line), and I_x is the area moment of inertia about the midspan chord line.

As an illustration of the effect of plan form, if a wing has the extreme amount of taper possible, the tip being a point, the value of I_x is half that of a rectangular wing having the same area and span, and C_l need be only half as large to give the same value of $R\cdot C$ or the same controllability in roll. The factor 12 in the denominator of the above formula is inserted so that for a rectangular wing the value of $\frac{S\,b^2}{12\,I_x}$ becomes unity and the rolling criterion becomes simply

$$R\,C=\frac{C_l}{C_L}$$

From another viewpoint $\frac{C_l}{C_L}$ gives the position of the lateral center of pressure in terms of the span; since for steady flight the lift is always constant and practically equal to the weight, the above ratio is always proportional to the actual rolling moment, and therefore to the tangential acceleration of the wing tip, regardless of speed, either above or below the stall.

Values of the lateral controllability criterion are given for four representative angles of attack: 0°, 10°, 20°, and 30°. The 0° value represents the condition for high speed. The 10° value represents the highest angle of attack, just below the stall, at which present-day ailerons give satisfactory lateral control on conventional airplanes. An angle of attack of 20° is well above the stall with the Clark Y airfoil and represents approximately the worst range in regard to turbulence and instability. The 30° angle is included here mainly for comparison with later tests on wings and control systems which are satisfactory at higher angles of attack.

A recent survey of a number of conventional airplanes showed that most of them had ailerons with equal up-and-down deflection, and that the average maximum deflection was about 25°. A maximum deflection of ±25° has therefore been assumed for the data on ailerons with equal up-and-down deflection in Table XIV. For the other aileron movements the maximum deflections have been selected to give substantially the same rolling control as the standard ailerons at an angle of attack of 10°.

Lateral control with sideslip.—The aileron control in a sideslip is important because the sideslip itself causes a rolling moment which, in all ordinary cases, will overpower the ailerons at very high angles of attack. The criterion which has been taken to cover this condition is the maximum angle of attack at which the ailerons can balance the rolling moment due to an angle of sideslip, or yaw, of 20°. Above this angle of attack this amount of sideslip will cause the airplane to roll against the ailerons at their assumed maximum deflection.

Yawing moment due to ailerons.—In the ideal case in which the rudder, the elevator, and the ailerons perform their main functions independently and without mutual interference, the ailerons should give only a rolling moment about the body axis and no tendency to yaw or pitch the airplane. The pitching moment is ordinarily negligible, but the yawing moment due to the ailerons is often large and in such a direction that it tends to make the airplane take a yawing motion against that which would normally accompany the roll given by the ailerons in a turn. This yawing motion causes a rolling moment opposing that due to the ailerons, and in some cases, particularly at high angles of attack just above the stall, this rolling moment due to yawing becomes stronger than that due to the ailerons, and the airplane rolls in the opposite direction.

If it is unavoidable that the ailerons cause some yawing as well as rolling moment, it is desirable that it be in such a direction that the secondary rolling effect aids the ailerons instead of opposing them. In fact, for general flying, it is probably advantageous to have an appreciable yawing moment accompanying the aileron deflection, if it is in the direction tending to aid the ailerons and make the airplane turn in the proper direction to avoid sideslip. A yawing moment of the opposite sense, however, is always undesirable at high angles of attack where it can often overpower the rudder and induce a rolling moment which will make the airplane roll against the ailerons themselves, sometimes starting into a spin.

This yawing tendency, if present, can be overcome only by the rudder, and the criterion used for it is simply the yawing moment coefficient with respect to the body axes C_n. The value of this coefficient on any particular airplane is approximately proportional to the rudder deflection required to overcome it, regardless of the angle of attack or the air speed. It is essential that the yawing moments be taken about the body axes, for they are often negative with respect to the wind axes but at the same time positive or favorable with respect to the body axes, these being the only ones upon which the pilot bases his maneuvers. The values of C_n given in the table of criterions (Table XIV) are with respect to the vertical body axis, taken as perpendicular to the midspan chord line and one-fourth of the chord back from the leading edge. They are given a negative sign if the secondary rolling effect opposes the rolling moment due to the ailerons, and a positive sign if the secondary rolling moment aids the ailerons. For acrobatic purposes it is desirable that this yawing moment be zero, but for ordinary flying it is likely that a positive yawing moment would be desirable.

The yawing moments do not always increase as the aileron deflection is increased, but sometimes reach a maximum negative value with partial deflection, after which they may become positive before the assumed maximum deflection is reached. For these cases both the positive value at maximum deflection and the maximum negative value at partial deflection are given in Table XIV, and if the deflection is other than the maximum it is indicated by letters and footnotes.

LATERAL STABILITY

In flight the lateral stability is dependent upon many factors, but the present wind-tunnel tests are confined to the tendency to roll caused directly either by rolling or by sideslip. Ordinarily, wings at angles of attack below the stall when rotated about the longitudinal axis are subjected to a damping moment tending to stop the roll. At the higher angles of attack beyond the stall they tend to rotate by themselves with the slightest disturbance, this of course being autorotation.

Angle of attack above which autorotation is self-starting.—The criterion that is used to compare the various ranges of autorotation is the angle of attack below which the wing is stable with respect to rolling in that it will not start to roll by itself. Below this angle of attack the lateral stability is satisfactory, but above it the wing is unstable in roll, which is an unsatisfactory flight condition.

Stability against rolling caused by gusts.—If given a rotational motion to start with, the wing models will sometimes continue to autorotate at angles of attack slightly lower than those at which they will start by themselves. As stated previously, flight tests have shown that under extremely gusty air conditions, even though an airplane is held as level as possible, it is likely to roll to the extent that $\frac{p'b}{2V}=0.05$. This has been taken as the worst case likely to be encountered; in the present investigation, tests have been made in which the wings have been forced to rotate at such a rate that $\frac{p'b}{2V}=0.05$, and the rolling moments due to rolling have been measured. A second and more severe lateral stability criterion obtained from these tests has been taken as the angle of attack below which the rolling moment tends to damp out the rolling.

This critical angle below which the wing is stable is also used as a criterion for the condition of 20° yaw and $\frac{p'b}{2V}=0.05$.

The above-mentioned angles show the critical range below which the stability is such that any rolling is damped out and above which the range of instability may be large or small, and the instability weak or intense. In order to show the degree of this instability, the maximum unstable rolling moment while rolling, C_λ, which occurs at any angle of attack and in either direction of rotation is given as a criterion for both 0° and 20° yaw, at $\frac{p'b}{2V}=0.05$. The maximum values of C_λ occur at angles of attack just above the stall and are greatly influenced by very slight imperfections in the form of the models. They should therefore be taken as indications only, rather than as absolute values.

CONTROL FORCE REQUIRED

A coefficient representing the force required on the control stick has been computed from the results of previous tests on hinge moments (reference 5) made with ailerons of different sizes on a Clark Y model wing. On account of the fact that various types of linkage are required for the different differential aileron movements, the hinge moments could not be used directly to indicate the relative values of the control force required, and it was necessary to assume certain control linkages. The linkages chosen are shown in Figure 2. The control force criterion is then given by the equation

$$CF=\frac{F\times l}{q\times c\times S\times C_L}$$

where F is the control force required and l represents the length of the control lever. As in the case of the rolling criterion, the C_L in the denominator gives the values of the coefficient the proper relation regardless of the angle of attack or air speed, steady flight being assumed. Values of the control force coefficient are given for the assumed maximum aileron deflection, the top of the control stick being given the same maximum travel in all cases.

DISCUSSION OF RESULTS

GENERAL PERFORMANCE

Referring to Table XIV, it will be noted that the maximum lift coefficients for all three wings with locked ailerons are within 2 per cent of the average value, 1.25. The slight differences are due to experimental errors in the construction and testing of the models. The minimum drag coefficients with the ailerons fixed neutral have the same value throughout, and so the speed-range ratio, $\frac{C_{L\ max}}{C_{D\ min}}$, is also essentially the same throughout.

With the ailerons allowed to float the lift coefficient falls off from 6 to 14 per cent, the great drop being with the short, wide ailerons. With the medium and the long, narrow ailerons the minimum drag also is less with the ailerons floating, so that the ratio $\frac{C_{L\ max}}{C_{D\ min}}$ is about the same as with the fixed ailerons. With the short, wide ailerons allowed to float, however, the minimum drag is appreciably greater and the speed-range ratio falls off substantially.

The rate-of-climb criterion is also the same for all three wings with fixed ailerons. It is slightly higher for the medium and narrow ailerons arranged to float, but is somewhat lower for the wide floating ailerons.

LATERAL CONTROLLABILITY

Rolling criterion.—It has been found from flight experience with several conventional airplanes that with average-sized ailerons having equal up-and-down deflections the lateral controllability is adequate up to angles of attack just below the stall, but that at the higher angles of attack it is unsatisfactory. Upon this basis the value of the rolling criterion $R\ C$ for the medium-sized ailerons of the present tests, with a maximum deflection of $\pm 25°$ at an angle of attack of 10°, is taken as a basic standard value representing the minimum value of the criterion for satisfactory control. For these conditions, $C_l = 0.079$ and $R\ C = 0.075$. For the other aileron chords the spans were selected to give about the same value of $R\ C$ at the 10° angle of attack. As is shown by Table XIV, the short, wide ailerons give a value about 3 per cent higher and the long, narrow ailerons a value about 6 per cent lower, all of these being taken with the same maximum deflection, $\pm 25°$.

Although the values of C_l are reasonably constant for the various angles of attack below the stall (fig. 15), the effective rolling control as shown by $R\ C$ is much greater for an angle of attack of 0° (high speed) than for 10°; that is, C_l is 0.075 at 0°, compared with 0.079 at 10°, while $R\ C$ is 0.204 at 0°, nearly three times its value of 0.075 at 10°. Thus, the actual rolling control is much greater than necessary at the high speed or 0° angle-of-attack condition.

As stated previously, the angle of attack of 20° represents the condition of maximum instability. It also happens to be about the highest angle of attack which can be maintained in a glide with conventional present-day airplanes having slightly more than average longitudinal control. The lateral controllability is in every case less at an angle of attack of 20° than the satisfactory values obtained at 10°.

The highest value of $R\ C$ at an angle of attack of 20° was obtained with the short, wide ailerons with upward travel only which have within 3 per cent of the satisfactory value at an angle of attack of 10°. The 20° angle of attack does not happen to be a good representative angle for these particular ailerons, as can be seen from Figure 16, which gives the variation of $R\ C$ with angle of attack. Between the angles of 20° and 23° the rolling control is in excess of the assumed satisfactory value. Between 10° and 20°, however, it falls about 15 per cent below, although even this value is probably satisfactory within the accuracy of our knowledge of what is required.

The peculiar increase of the values of $R\ C$ with angle of attack which occurred with the short, wide ailerons with up-only deflection is evident to a lesser extent with the differential movements of the same ailerons. It is also noticeable but of very small magnitude with the medium-sized ailerons. It is not apparent in the case of the long, narrow ones.

With the short, wide ailerons, the extreme differential movement was the next best at $\alpha = 20°$, followed by the floating arrangement, differential movement No. 1, and finally by the equal up-and-down movement which gave a rolling criterion only 59 per cent of the assumed satisfactory value at an angle of attack of 10°.

The long, narrow ailerons gave the poorest controllability at an angle of attack of 20°, the values of $R\ C$ with the various movements being around one-third of the satisfactory value. The standard, or medium-sized, ailerons gave values in between those of the extreme sizes. The best value was found with the extreme differential movement and was about three-fourths of the satisfactory standard value.

With all the ailerons the equal up-and-down movements gave the poorest rolling moments at an angle of attack of 20°, and in each case the best moments were obtained with the extreme differential and up-only movements. As previously stated, at the high angles of attack above the stall, particularly those between 20° and 25°, the air flow over the wings was very turbulent, which makes the accuracy of the data somewhat doubtful.

At the 30° angle of attack, which was included mainly to enable later comparisons with slotted wings, etc., the values of $R\,C$ were very low for all the ailerons. The highest, strangely, occurred with the long, narrow ailerons having equal up-and-down deflection, although these gave the lowest values at an angle of attack of 20°.

Lateral control with sideslip.—The order of merit of the various ailerons with respect to the lateral controllability at an angle of attack of 20° and with 20° sideslip is approximately the same as without the sideslip at the same angle of attack. The short, wide ailerons with the assumed maximum deflection gave a rolling moment sufficient to overcome the rolling moment due to an angle of yaw of 20° up to an angle of

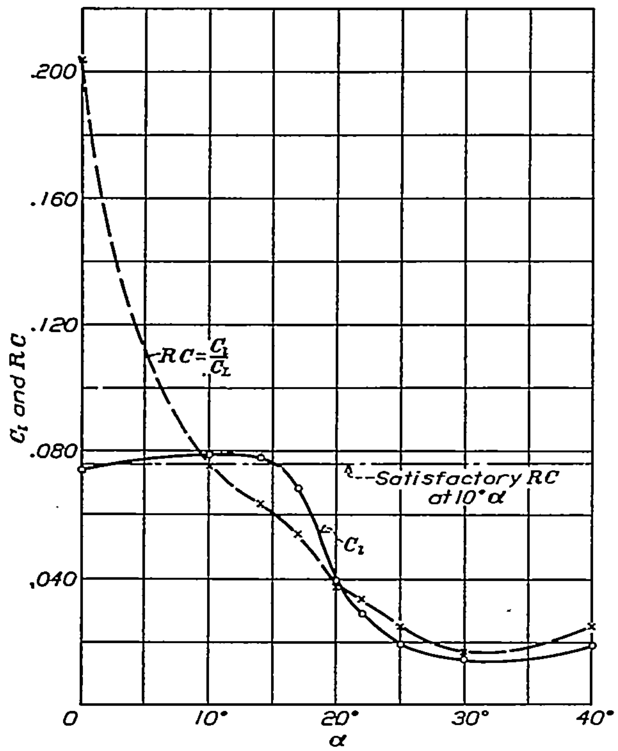


FIGURE 15.—Relation between rolling-moment coefficient (body axes) and rolling criterion for 25 per cent chord ailerons fixed up-and-down 25°

attack of 25° with upward movement only, 24° with the ailerons arranged to float, and 22° with the extreme differential movement. The medium-sized ailerons with upward movement only and the extreme differential arrangement are next in order. Above the stall none of the ailerons with the equal up-and-down or with the ordinary differential movements gave an appreciable amount of control against 20° sideslip. Below the stall, all the ailerons have an increased margin of excess control moment as the angle of attack is reduced.

Yawing moment due to ailerons.—It is interesting to compare the yawing moments due to ailerons with the average values which can be obtained with rudders on conventional airplanes. These rudder values range from $C_n=0.005$ to 0.015, the average value being about 0.01 for the angles of attack below the stall and 0.007 for an angle of attack of 20°. As shown in Table XIV, negative (or undesirable) yawing moments are obtained with all three sizes of ailerons with the equal up-and-down deflections, and at the angles of attack just above the stall they are greater than can be obtained with the average rudder. With the average differential movement (No. 1) the conditions are somewhat better, but

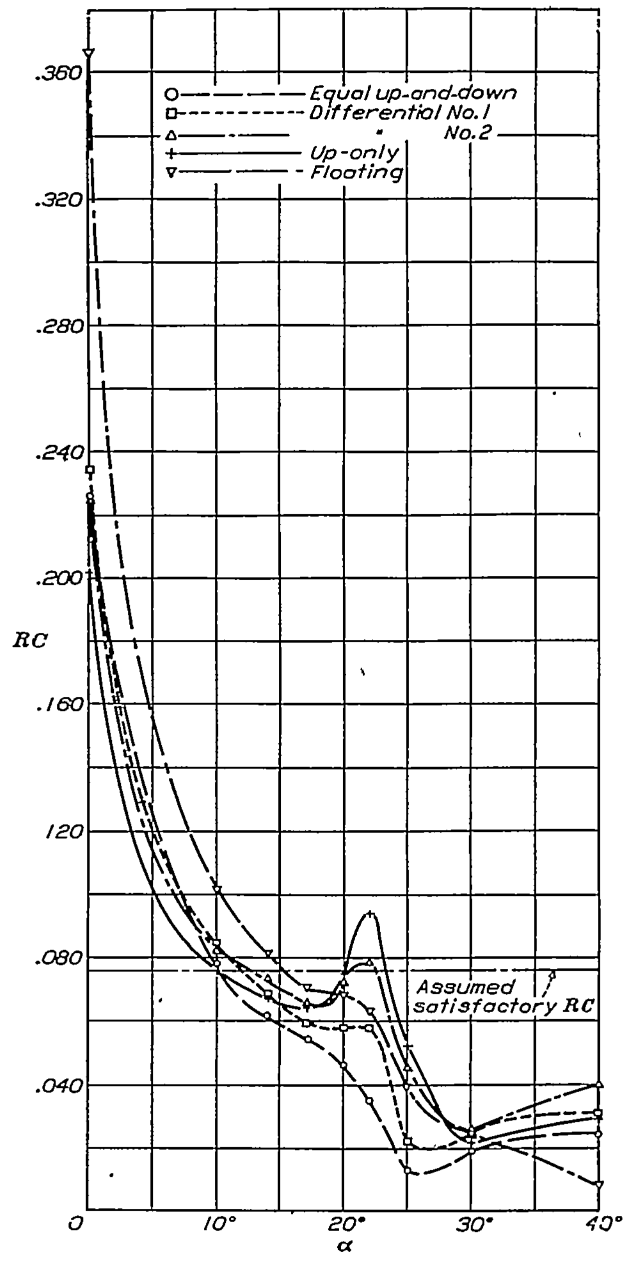


FIGURE 16.—Rolling criterion, 40 per cent c by 30 per cent $b/2$ ailerons with various movements

there are still some rather large undesirable negative values.

The ailerons of all three sizes with extreme differential movements gave very strong positive yawing moments with full deflection, but with partial aileron deflection at angles of attack above the stall they gave negative yawing moments about equivalent to those obtained with an average rudder. The ailerons with up-only movement gave very strong positive yawing moments below the stall with all three sizes, and also well above the stall with the medium and the short, wide ailerons. The greatest yawing moments were obtained with the short, wide ailerons, and at an angle of attack of 20° these reached values about four times that obtained with the average rudder. The ailerons with up-only movement when deflected about 10° had small negative or adverse yawing moments at angles of attack above the stall, but had positive values with full aileron deflection. This condition suggests the possibility of eliminating the negative yawing moment entirely by rigging the ailerons with about 10° upward deflection to start with and then giving them upward movement only or possibly an extreme differential arrangement.

The only aileron condition tested which gave no adverse yawing moments at any angle of attack was that with the short, wide ailerons arranged to float. The positive yawing moments were small at the low angles of attack corresponding to high speed and cruising flight, but were high above the stall, where they should be a great help in obtaining good control. The medium and the long, narrow floating ailerons had relatively small positive and negative yawing moments at all angles of attack, even above the stall.

LATERAL STABILITY

Angle of attack above which autorotation is self-starting.—The angle of attack for initial instability in rolling, that is, the angle at which the airfoil will start to rotate by itself if mounted on a ball-bearing spindle parallel to the air flow, was very nearly the same for all the ailerons tested. In every case, allowing the ailerons to float reduced both the rate and range of autorotation, the effect being greatest with the wide, short ailerons. The wing with the narrow floating ailerons was stable up to an angle of attack 2° higher than with fixed ailerons. The wing with the widest floating ailerons had only a weak rotation throughout two small ranges, 19° to 21° and 28° to 31°.

Stability against rolling caused by gusts.—The angle of attack above which the rolling moment due to rolling C_λ is unstable with a rotation such that $\frac{p'b}{2V}=0.05$ is a more severe criterion of the lateral stability, and the values are slightly lower. In each case the range of stability was raised slightly by allowing the ailerons to float. This effect was small, however, and it may be stated with sufficient accuracy that all cases tested were found to be stable against rolling below the stall and unstable above. With 20° yaw, the angle of attack at which C_λ becomes unstable is 5° to 7° lower than with 0° yaw.

The maximum unstable value of C_λ at $\frac{p'b}{2V}=0.05$ is rather high with all the fixed ailerons, the values differing slightly for the different wing models on account of small imperfections in form. These unstable values were reduced to less than half by allowing the medium ailerons to float, and to one-fourth by allowing the short, wide ailerons to float. At 20° yaw and $\frac{p'b}{2V}=0.05$ the maximum unstable value of C_λ is great in one direction in every case, being appreciably greater than the value of C_l' due to the ailerons. The maximum unstable values of C_λ occur at very high angles of attack, however, and could be overcome up to angles of attack of at least 20° by the short, wide ailerons with extreme differential movement, upward movement only, or arranged to float. With the floating ailerons the unstable value of C_λ is reduced approximately to half.

CONTROL FORCE REQUIRED

In general the control force required to deflect the ailerons the assumed maximum amount is largest for the ailerons having the widest chord. It is about three times as great for the short, wide as for the long, narrow ones, and is nearly twice as great for the short, wide ones as for the medium ones. For any particular size the control force is greater for the up-only, extreme differential, and floating arrangements than for the ordinary differential and equal up-and-down systems, both of which had about the same values.

SUMMARY OF RESULTS

Comparison of the best ailerons.—The most promising ailerons are compared with reference to the standard ones having a chord of 25 per cent and equal up-and-down deflection. One of the outstanding features of the standard ailerons is that at angles of attack of 20° to 30° the values of the rolling criterion $R\ C$ are only 50 per cent or less of the assumed minimum satisfactory value which is obtained at an angle of attack of 10°. They have good control against 20° sideslip at low angles of attack, but this control decreases as the angle of attack goes up until at an angle of 20°, or just as the wing becomes well stalled, the ailerons just balance the rolling moment due to yaw. Above this angle of attack the ailerons are overpowered by 20° yaw. The yawing moment due to the standard ailerons is negative or unfavorable at all angles of attack, and for the assumed full deflection at angles of attack above the stall the yawing moments due to the ailerons are greater than the yawing moment which can be obtained with the average rudder. Just below the stall the yawing moments are about one-half of the value of those obtained with the average rudder. The lateral stability as shown by the tendency to damp out a rolling motion is satisfactory at the low angles of attack, even with sideslip as great as 20°, but above the stall the wing is very unstable and tends to roll at a rapid rate. The control force required for the standard aileron may be taken as a satisfactory average value for airplanes of medium size and speed. This control force is more than twice as great at high speed as it is near the stall, but complete deflection is not ordinarily required at the high-speed condition.

Ailerons of about the standard size are frequently used with a differential motion similar to the No. 1 movement in this series of tests. With this differential movement the ailerons are somewhat better than the standard in regard to controllability at the high angles of attack but are nearly as bad in their unfavorable yawing moments. At the low speeds where complete deflection is often necessary, the control force required for the assumed complete deflection is slightly less than that required for the equal up-and-down movement.

If suitable operating mechanism were developed, the best all-around ailerons of those tested for light and small airplanes are probably the short, wide ones with upward deflection only. This combination gives exceptionally good control at the high angles of attack, the value of $R\ C$ at 20° being 97 per cent of the satisfactory value at 10°.. With maximum aileron deflection the yawing moments have strong positive values at all angles of attack, the only adverse values being small and occurring with small aileron deflection. Also, the control against sideslip is the most powerful of any of the aileron combinations tested, it being effective up to an angle of attack of 25° as compared with 20° for the standard ailerons. The forces required on the control stick at medium and low speeds are slightly more than double those for the standard (25 per cent chord) ailerons with equal up-and-down deflection.

For somewhat larger airplanes the short, wide ailerons with extreme differential motion are probably the best of those tested. With this arrangement the force required on the control stick at low speeds is about the same as that with the standard ailerons. The yawing moments are mainly favorable, the adverse negative values being confined to small aileron deflections and the rolling control at high angles of attack is relatively good, the value of $R\ C$ at 20° being 88 per cent of the value at 10°.

For an acrobatic airplane, in which case it is desirable to have each control independent and therefore to have zero yawing moment due to the ailerons, the medium or the long, narrow ailerons arranged to float would probably meet the requirements best. Considering angles of attack below the stall only, very small yawing moments are produced by the long, narrow ailerons with the average differential movement (No. 1).

CONCLUSIONS

1. Ailerons of average size with the commonly used differential and equal up-and-down movements gave inadequate controllability at angles of attack above the stall, the rolling moments being only one-half to two-thirds of the assumed minimum satisfactory value.

2. At angles of attack above the stall, rolling moments closely approaching the minimum desirable were given only by the short, wide ailerons, either with extreme differential movement or with upward movement only.

3. The only arrangement with which no adverse yawing moments were obtained was with the short, wide ailerons arranged to float. These gave rather large favorable yawing moments at the high angles of attack and very small ones at the low angles of attack.

4. The ailerons giving the smallest positive or negative yawing moments at all angles of attack were, in the order named, (1) the medium-sized floating ailerons, (2) the long, narrow floating ailerons, and (3) the medium-sized ailerons with the average differential movement. These latter medium-sized ailerons with the average differential movement, at an angle of attack of 20°, gave an adverse yawing moment equal to that which can be obtained with an average rudder.

5. Large yawing moments aiding the rolling were given with the assumed maximum deflection by the short, wide and the medium-sized ailerons with upward movement only. Small aileron deflections at angles of attack above the stall, however, gave small adverse yawing moments.

6. The results indicate that the adverse yawing moments could be entirely eliminated by rigging both ailerons up about 10° for the neutral position and then giving them an upward movement only or an extreme differential movement. It is recommended that further tests with these conditions be made.

7. When floating, the ailerons gave a substantial improvement in the lateral stability, the effect being greater with the short, wide ailerons.

8. Allowing the ailerons to float reduced the maximum lift coefficient but slightly improved the characteristics in regard to climbing performance with all except the widest chord ailerons.

Langley Memorial Aeronautical Laboratory,
National Advisory Committee for Aeronautics,
Langley Field, Va., *December 10, 1931.*

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TABLE II

FORCE TESTS. 10 BY 60 IN. CLARK Y WING WITH PLAIN AILERONS 25 PER CENT c BY 40 PER CENT $b/2$
YAW=0° R. N.=609,000 VELOCITY=80 M. P. H.

α		−10°	−5°	−3°	0°	5°	10°	12°	13°	14°	15°	16°	17°	20°	25°	30°	40°	50°	60°
	δ_A	AILERONS LOCKED—NEUTRAL																	
C_L	0°	−0.325	0.018	0.161	0.365	0.724	1.037	1.145	1.187	1.232	1.260	1.266	1.270	1.020	0.790	0.845	0.785	0.693	0.578
C_D	0°	.032	.016	.016	.021	.046	.086	.106	.117	.127	.139	.157	.174	.314	.416	.543	.713	.876	1.042
LEFT AILERON DOWN. RIGHT AILERON UP																			
C_l'	10°	-----	-----	-----	0.038	-----	0.034	0.033	-----	0.032	-----	0.029	-----	0.012	-----	−0.003	−0.003	-----	-----
C_n'	10°	-----	-----	-----	−.003	-----	−.008	−.009	-----	−.010	-----	−.011	-----	−.012	-----	−.003	−.006	-----	-----
C_l'	20°	-----	-----	-----	.065	-----	.069	.066	-----	.064	-----	.058	-----	.026	-----	.005	.009	-----	-----
C_n'	20°	-----	-----	-----	−.006	-----	−.016	−.017	-----	−.019	-----	−.020	-----	−.020	-----	−.011	−.015	-----	-----
C_l'	30°	-----	-----	-----	.084	-----	.085	.088	-----	.088	-----	.081	-----	.042	-----	.011	.015	-----	-----
C_n'	30°	-----	-----	-----	−.007	-----	−.020	−.023	-----	−.025	-----	−.028	-----	−.026	-----	−.018	−.023	-----	-----
C_l'	40°	-----	-----	-----	.100	-----	.099	.098	-----	.095	-----	.087	-----	.034	-----	.009	.023	-----	-----
C_n'	40°	-----	-----	-----	−.007	-----	−.021	−.024	-----	−.026	-----	−.028	-----	−.026	-----	−.018	−.028	-----	-----
C_l'	50°	-----	-----	-----	.114	-----	.109	.108	-----	.106	-----	.097	-----	.049	-----	.001	.005	-----	-----
C_n'	50°	-----	-----	-----	−.006	-----	−.021	−.024	-----	−.027	-----	−.030	-----	−.029	-----	−.021	−.024	-----	-----
LEFT AILERON DOWN. RIGHT AILERON 0°																			
C_l'	10°	-----	-----	-----	0.018	-----	0.015	-----	-----	0.014	-----	0.014	-----	0.005	-----	−0.007	0.001	-----	-----
C_n'	10°	-----	-----	-----	−.002	-----	−.005	-----	-----	−.005	-----	−.006	-----	−.005	-----	0	−.003	-----	-----
C_l'	20°	-----	-----	-----	.029	-----	.030	-----	-----	.028	-----	.024	-----	.002	-----	−.009	0	-----	-----
C_n'	20°	-----	-----	-----	−.006	-----	−.011	-----	-----	−.012	-----	−.013	-----	−.009	-----	−.004	−.007	-----	-----
C_l'	30°	-----	-----	-----	.038	-----	.036	-----	-----	.036	-----	.030	-----	.003	-----	−.016	−.002	-----	-----
C_n'	30°	-----	-----	-----	−.011	-----	−.016	-----	-----	−.018	-----	−.019	-----	−.012	-----	−.005	−.011	-----	-----
C_l'	40°	-----	-----	-----	.045	-----	.039	-----	-----	.037	-----	.031	-----	.002	-----	−.011	−.004	-----	-----
C_n'	40°	-----	-----	-----	−.015	-----	−.020	-----	-----	−.022	-----	−.023	-----	−.016	-----	−.012	−.015	-----	-----
RIGHT AILERON UP. LEFT AILERON 0°																			
C_l'	10°	-----	-----	-----	0.019	-----	0.019	-----	-----	0.017	-----	0.016	-----	0.006	-----	−0.005	0.002	-----	-----
C_n'	10°	-----	-----	-----	0	-----	−.003	-----	-----	−.004	-----	−.005	-----	−.005	-----	0	−.003	-----	-----
C_l'	20°	-----	-----	-----	.037	-----	.041	-----	-----	.038	-----	.036	-----	.025	-----	.003	.007	-----	-----
C_n'	20°	-----	-----	-----	.001	-----	−.005	-----	-----	−.007	-----	−.009	-----	−.011	-----	−.005	−.007	-----	-----
C_l	30°	-----	-----	-----	.046	-----	.049	-----	-----	.050	-----	.049	-----	.039	-----	.013	.015	-----	-----
C_n'	30°	-----	-----	-----	.004	-----	−.003	-----	-----	−.006	-----	−.008	-----	−.013	-----	−.007	−.010	-----	-----
C_l'	40°	-----	-----	-----	.056	-----	.059	-----	-----	.058	-----	.055	-----	.042	-----	.007	.023	-----	-----
C_n'	40°	-----	-----	-----	.008	-----	−.001	-----	-----	−.004	-----	−.006	-----	−.009	-----	−.002	−.013	-----	-----
C_l'	60°	-----	-----	-----	.072	-----	.077	-----	-----	.076	-----	.071	-----	.056	-----	.001	.009	-----	-----
C_n'	60°	-----	-----	-----	.016	-----	.005	-----	-----	.001	-----	−.002	-----	−.007	-----	−.002	−.006	-----	-----
C_l'	80°	-----	-----	-----	.077	-----	.084	-----	-----	.082	-----	.078	-----	.063	-----	.001	.007	-----	-----
C_n'	80°	-----	-----	-----	.022	-----	.010	-----	-----	.005	-----	.003	-----	−.002	-----	−.002	−.006	-----	-----
AILERONS FLOATING—NEUTRAL																			
C_L	0°	−0.323	−0.049	0.087	0.293	0.647	0.951	1.051	1.103	1.138	1.166	1.168	1.161	1.120	0.630	0.618	0.626	0.572	0.486
C_D	0°	-----	.017	.015	.018	.038	.071	.088	.096	.103	.113	.129	.143	.192	.341	.412	.585	.759	.917
δ_{AF}	0°	−3°	−5°	−6°	−6°	−4°	−9°	−10°	−10°	−10°	−12°	−12°	−13°	−16°	−30°	−34°	−32°	−39°	−43°
LEFT AILERON DOWN. RIGHT AILERON UP																			
C_l'	10°	-----	-----	-----	0.038	-----	0.038	-----	-----	0.036	-----	0.034	-----	0.018	-----	−0.010	0.016	-----	-----
C_n'	10°	-----	-----	-----	−.001	-----	−.006	-----	-----	−.006	-----	−.007	-----	−.009	-----	−.005	−.004	-----	-----
δ_{AF}	10°	-----	-----	-----	16°	-----	12°	-----	-----	10°	-----	9°	-----	3°	-----	−28°	−29°	-----	-----
C_l'	20°	-----	-----	-----	.062	-----	.062	-----	-----	.059	-----	.054	-----	.033	-----	[a]−.015	[a]−.003	-----	-----
C_n'	20°	-----	-----	-----	−.002	-----	−.009	-----	-----	−.011	-----	−.012	-----	−.014	-----	[a].005	[a].005	-----	-----
δ_{AF}	20°	-----	-----	-----	14°	-----	14°	-----	-----	11°	-----	9°	-----	6°	-----	1°	−7°	-----	-----
C_l'	30°	-----	-----	-----	.081	-----	.085	-----	-----	.080	-----	.073	-----	[a].039	-----	[a]−.008	−.003	-----	-----
C_n'	30°	-----	-----	-----	−.003	-----	−.012	-----	-----	−.015	-----	−.017	-----	[a]−.017	-----	[a].005	.005	-----	-----
δ_{AF}	30°	-----	-----	-----	23°	-----	19°	-----	-----	19°	-----	19°	-----	14°	-----	25°	34°	-----	-----
C_l'	40°	-----	-----	-----	.100	-----	.103	-----	-----	.100	-----	.093	-----	[a].045	-----	[b].002	.003	-----	-----
C_n'	40°	-----	-----	-----	−.003	-----	−.014	-----	-----	−.019	-----	−.020	-----	[a]−.018	-----	[b]−.001	−.001	-----	-----
δ_{AF}	40°	-----	-----	-----	30°	-----	31°	-----	-----	27°	-----	27°	-----	23°	-----	−14°	−15°	-----	-----
C_l'	50°	-----	-----	-----	.113	-----	.112	-----	-----	.108	-----	[a].101	-----	[b].052	-----	.009	.009	-----	-----
C_n'	50°	-----	-----	-----	−.003	-----	−.016	-----	-----	−.020	-----	[a].021	-----	[b]−.018	-----	−.007	−.009	-----	-----
δ_{AF}	50°	-----	-----	-----	48°	-----	42°	-----	-----	38°	-----	35°	-----	28°	-----	6°	5°	-----	-----

[a] Ailerons fluctuate ±1° to ±2° under these conditions. [b] Ailerons fluctuate ±3° to ±4° under these conditions.

TABLE III

FORCE TESTS 10 BY 60 IN. CLARK Y WING WITH PLAIN AILERONS 25 PER CENT c BY 40 PER CENT $b/2$
YAW=−20° R. N. =609,000 VELOCITY=80 M. P. H.

α		−10°	−5°	−3°	0°	5°	10°	12°	13°	14°	15°	16°	17°	20°	25°	30°	40°	50°	60°
	δ_A	AILERONS LOCKED—NEUTRAL																	
C_L	0°	−0.302	0.010	0.138	0.333	0.654	0.943	1.040	1.082	1.110	1.153	1.164	1.194	1.176	0.888	0.872	0.796	0.734	0.616
C_D	0°	.031	.016	.017	.021	.043	.079	.094	.103	.112	.123	.132	.146	.217	.416	.507	.666	.866	1.035
C_l'	0°	.001	.004	.005	−.007	−.009	−.013	−.016	−.017	−.020	−.025	−.031	−.040	−.008	−.100	−.100	−.057	−.018	−.045
C_n'	0°	.002	.002	.002	.002	.002	.006	.008	.008	.010	.011	.013	.015	.019	.046	.053	.046	.050	.050
LEFT AILERON DOWN. RIGHT AILERON UP																			
C_l'	10°				0.034		0.031	0.032		0.031		0.030		0.024		0.006	0.003		
C_n'	10°				−.003		−.007	−.009		−.011		−.011		−.012		−.011	−.010		
C_l'	20°				.063		.063	.063		.062		.061		.050		.017	.005		
C_n'	20°				−.005		−.015	−.017		−.020		−.020		−.023		−.024	−.016		
C_l'	30°				.084		.088	.088		.088		.087		.076		.030	.008		
C_n'	30°				−.008		−.023	−.027		−.030		−.031		−.035		−.038	−.020		
C_l'	40°				.096		.101	.101		.102		.103		.092		.046	.011		
C_n'	40°				−.006		−.022	−.028		−.030		−.031		−.035		−.048	−.028		
C_l'	50°				.104		.111	.112		.113		.116		.102		.050	.015		
C_n'	50°				−.007		−.023	−.027		−.031		−.033		−.036		−.048	−.028		
LEFT AILERON DOWN RIGHT AILERON 0°																			
C_l'	10°				0.014		0.013			0.012		0.012		0.006		0.003	0.002		
C_n'	10°				−.002		−.003			−.005		−.005		−.004		−.005	−.005		
C_l'	20°				.026		.024			.023		.021		.012		.005	.003		
C_n'	20°				−.006		−.009			−.011		−.010		−.009		−.009	−.009		
C_l'	30°				.034		.032			.032		.030		.016		.006	.003		
C_n'	30°				−.010		−.015			−.017		−.017		−.015		−.014	−.014		
C_l'	40°				.037		.035			.036		.035		.018		.005	.002		
C_n'	40°				−.014		−.020			−.023		−.022		−.020		−.017	−.017		
RIGHT AILERON UP. LEFT AILERON 0°																			
C_l'	10°				0.019		0.019			0.018		0.018		0.017		0.002	0.001		
C_n'	10°				−.001		−.003			−.006		−.006		−.007		−.005	−.004		
C_l'	20°				.038		.039			.040		.040		.038		.011	.003		
C_n'	20°				.001		−.005			−.009		−.010		−.013		−.014	−.007		
C_l'	30°				.051		.056			.056		.057		.056		.021	.007		
C_n'	30°				.004		−.005			−.010		−.012		−.016		−.022	−.010		
C_l'	40°				.058		.065			.066		.067		.066		.035	.015		
C_n'	40°				.009		−.001			−.007		−.009		−.013		−.025	−.010		
C_l'	60°				.067		.079			.083		.086		.087		.047	.014		
C_n'	60°				.014		.004			−.002		−.004		−.008		−.023	−.010		
C_l'	80°				.072		.085			.090		.093		.098		.053	.013		
C_n'	80°				.020		.009			.003		0		−.004		−.021	−.010		
AILERONS FLOATING—NEUTRAL																			
C_L	0°	−0.329	−0.027	0.101	0.283	0.576	0.858	0.949	0.993	1.028	1.053	1.076	1.081	1.054	0.788	0.764	0.674	0.615	0.512
C_D	0°	.032	.017	.015	.019	.035	.065	.080	.087	.095	.101	.112	.119	.173	.355	.443	.586	.750	.897
C_l'	0°	−.001	−.005	−.007	−.008	−.009	−.011	−.013	−.014	−.017	−.018	−.023	−.020	−.056	−.088	−.089	−.050	−.045	−.037
C_n'	0°	.002	.001	.001	.002	−.003	.005	.006	.007	.008	.009	.010	.010	.021	.027	.040	.017	.017	.052
δ_{AF}	0°	0°	−2°	−3°	−5°	−7°	−10°	−11°	−12°	−12°	−13°	−14°	−16°	−22°	−25°	−31°	−42°	−43°	−46°
LEFT AILERON DOWN. RIGHT AILERON UP																			
C_l'	10°				0.034		0.031			0.029		0.028		0.021		0.013	0.010		
C_n'	10°				−.001		−.004			−.005		−.005		−.005		−.006	−.003		
δ_{AF}	10°				18°		10°			6°		4°		7°		0°	−7°		
C_l'	20°				.061		.060			.058		.055		.040		.028	[a].016		
C_n'	20°				−.002		−.009			−.011		−.011		−.011		−.014	[a]−.007		
δ_{AF}	20°				17°		12°			9°		9°		4°		−31°	−30°		
C_l'	30°				.083		.083			.081		.078		.059		.039	[a].007		
C_n'	30°				−.002		−.012			−.015		−.017		−.026		−.022	[a]−.002		
δ_{AF}	30°				26°		22°			20°		21°		21°		16°	20°		
C_l'	40°				.093		.099			.099		.095		.073		[b].046	.009		
C_n'	40°				−.002		−.014			−.019		−.021		−.031		[b]−.029	−.005		
δ_{AF}	40°				36°		32°			31°		26°		32°		28°	−18°		
C_l'	50°				.103		.109			.111		[a].109		[a].084		[a].062	[b].017		
C_n'	50°				−.003		−.015			−.021		[a]−.023		[a]−.034		[a]−.034	[b]−.014		
δ_{AF}	50°				45°		40°			41°		41°		44°		39°	6°		

[a] Ailerons fluctuate ±1° to ±2° under these conditions.

[b] Ailerons fluctuate ±3° to ±4° under these conditions.

TABLE IV

ROTATION TESTS. 10 BY 60 IN. CLARK Y WING WITH PLAIN AILERONS 25 PER CENT *c* BY 40 PER CENT *b*/2

C_λ is given for forced rotation at $\frac{p'b}{2V}=0.05\begin{cases}(+)\text{ aiding rotation}\\(-)\text{ damping rotation}\end{cases}$

$\frac{p'b}{2V}$ values are for free rotation

Yaw=0° Velocity=80 m. p. h. R. N.=609,000

	α	0°	12°	14°	16°	18°	19°	20°	22°	23°	25°	26°	27°	28°	30°	32°	35°	38°	40°
AILERONS LOCKED—NEUTRAL																			
(+) Rotation (clockwise)	C_λ	−0.0220	−0.0190	−0.0160	−0.0030	0.0065	0.0125	0.0370	0.0480	0.0440	0.0020	------	------	------	−0.0015	------	------	------	−0.0020
	$\frac{p'b}{2V}$	------	------	------	(a)	.310	------	.331	.336	------	.366	0.361	0.398	(a)	------	------	------	------	------
(−) Rotation (counter clockwise)	C_λ	−.0210	−.0190	−.0160	−.0050	.0065	.0115	.0400	.0230	.0150	.0050	------	------	------	−.0010	------	------	------	−.0015
	$\frac{p'b}{2V}$	------	------	------	(a)	.310	------	.328	.352	------	.365	.375	.389	(a)	------	------	------	------	------
AILERONS FLOATING—NEUTRAL																			
(+) Rotation (clockwise)	C_λ	−0.0233	−0.0250	−0.0237	−0.0194	−0.0094	------	−0.0048	0.0166	------	0.0045	------	------	------	−0.0002	------	------	------	−0.0053
	$\frac{p'b}{2V}$	------	------	------	------	------	------	.219	.228	0.237	.286	------	------	0.362	.380	0.054	------	------	------
(−) Rotation (counter clockwise)	C_λ	−.0170	−.0167	−.0153	−.0105	−.0036	------	−.0005	.0033	------	.0098	------	------	------	−.0022	------	------	------	−.0028
	$\frac{p'b}{2V}$	------	------	------	------	------	------	------	.242	.238	.291	------	------	.278	------	------	------	------	------

[a] Not self-starting.

TABLE V

ROTATION TESTS. 10 IN. BY 60 IN. CLARK Y WING WITH PLAIN AILERONS 25 PER CENT *c* BY 40 PER CENT *b*/2

C_λ is given for forced rotation at $\frac{p'b}{2V}=0.05\begin{cases}(+)\text{ aiding rotation}\\(-)\text{ damping rotation}\end{cases}$

Yaw=−20° Velocity=80 m. p. h. R. N.=609,000

	α	0°	12°	14°	16°	18°	19°	20°	22°	23°	25°	26°	28°	29°	30°	32°	35°	38°	40°
AILERONS LOCKED—NEUTRAL																			
(−) Rotation (counter-clockwise)	C_λ	−0.0135	0.0014	0.0082	0.0192	0.0394	------	0.0602	0.0930	------	0.0832	------	------	------	0.0742	------	------	------	0.0463
(+) Rotation (clockwise)	C_λ	−.0260	−.0364	−.0398	−.0484	−.0596	------	−.0668	−.0728	------	−.0820	------	------	------	−.0760	------	------	------	−.0530
AILERONS FLOATING—NEUTRAL																			
(−) Rotation (counter-clockwise)	C_λ	−0.0162	−0.0078	−0.0036	0.0026	0.0156	------	0.0350	0.0667	------	0.0710	------	------	------	0.0700	------	------	------	0.0552
(+) Rotation (clockwise)	C_λ	−.0212	−.0275	−.0302	−.0356	−.0450	------	−.0536	−.0795	------	−.0738	------	------	------	−.0756	------	------	------	−.0542

TABLE VI

FORCE TESTS. 10 BY 60 IN. CLARK Y WING WITH AILERONS 15 PER CENT c BY 60 PER CENT $b/2$
0° YAW R. N.=609,000 VELOCITY=80 M. P. H.

α		−10°	−5°	−3°	0°	5°	10°	12°	14°	16°	17°	18°	20°	22°	25°	30°	40°	50°	60°
	δ_A	AILERONS LOCKED—NEUTRAL																	
C_L	0°	−0.328	−0.015	0.125	0.326	0.674	1.013	1.122	1.194	1.222	1.215	1.215	1.029	0.897	0.780	0.860	0.770	0.680	0.553
C_D	0°	.066	.017	.016	.020	.042	.082	.103	.122	.151	.170	.186	.290	.341	.411	.533	.701	.868	1.032
RIGHT AILERON UP. LEFT AILERON DOWN																			
C_l'	10°				0.037		0.039		0.035		0.028		0.007	0.005	0.019	0.011	0.006		
C_n'	10°				−.003		−.009		−.010		−.010		−.010	−.007	−.010	−.009	−.008		
C_l'	20°				.064		.063		.058		.047		.018	.007	.028	.030	.014		
C_n'	20°				−.005		−.014		−.016		−.020		−.018	−.014	−.017	−.019	−.016		
C_l'	30°				.077		.075		.068		.053		.012	.011	.037	.043	.023		
C_n'	30°				−.006		−.007		−.020		−.023		−.020	−.017	−.022	−.026	−.023		
C_l'	40°				.097		.093		.083		.060		.017	.005	.026	.022	.012		
C_n'	40°				−.008		−.020		−.024		−.025		−.023	−.019	−.021	−.022	−.020		
C_l'	50°				.112		.106		.095		.066		.021	.006	.024	.018	.009		
C_n'	50°				−.008		−.022		−.026		−.026		−.024	−.021	−.022	−.025	−.022		
LEFT AILERON DOWN. RIGHT AILERON 0°																			
C_l'	10°				0.016		0.020		0.014		0.012		0.004	0.001	−0.007	0.004	0.003		
C_n'	10°				−.002		−.005		−.005		−.005		−.005	−.003	−.003	−.004	−.005		
C_l'	20°				.026		.031		.028		.018		.001	−.001	−.004	.008	.003		
C_n'	20°				−.005		−.009		−.010		−.010		−.009	−.006	−.007	−.010	−.009		
C_l'	30°				.036		.034		.033		.025		−.002	−.004	−.002	.010	.004		
C_n'	30°				−.008		−.013		−.014		−.015		−.011	−.009	−.010	−.014	−.013		
C_l'	40°				.044		.039		.036		.024		−.006	−.006	.002	.014	.007		
C_n'	40°				−.012		−.017		−.018		−.018		−.014	−.012	−.015	−.020	−.016		
RIGHT AILERON UP. LEFT AILERON 0°																			
C_l'	10°				0.020		0.019		0.018		0.018		0.004	0.005	0.017	0.006	0.004		
C_n'	10°				−.001		−.004		−.005		−.006		−.005	−.004	−.007	−.004	−.004		
C_l'	20°				.037		.033		.037		.031		.015	.011	.024	.020	.009		
C_n'	20°				−.001		−.005		−.006		−.009		−.009	−.008	−.009	−.010	−.008		
C_l'	30°				.043		.039		.034		.029		.010	.015	.023	.017	.019		
C_n'	30°				.002		−.004		−.006		−.007		−.007	−.007	−.007	−.007	−.011		
C_l'	40°				.055		.053		.045		.039		.018	.013	.017	.011	.008		
C_n'	40°				.004		−.003		−.006		−.007		−.008	−.007	−.007	−.005	−.005		
C_l'	60°				.067		.066		.058		.047		.029	.017	.018	.007	.007		
C_n'	60°				.010		0		−.003		−.005		−.007	−.006	−.006	−.005	−.006		
C_l'	80°				.072		.072		.063		.052		.035	.021	.017	.007	.007		
C_n'	80°				.015		.004		0		−.002		−.005	−.004	−.004	−.005	−.005		
AILERONS FLOATING—NEUTRAL																			
C_L	0°	−0.366	−0.047	0.092	0.285	0.635	0.957	1.063	1.122	1.120	1.110	1.090	1.045	0.760	0.640	0.660	0.635	0.582	0.472
C_D	0°	.058	.016	.014	.017	.036	.071	.087	.102	.129	.139	.152	.183	.288	.342	.426	.589	.767	.917
δ_{AF}	0°	−2°	−7°	−5°	−3°	−2°	−8°	−6°	−8°	−9°	−12°	−14°	−16°	−18°	−20°	−21°	−23°	−28°	−33°
RIGHT AILERON UP. LEFT AILERON DOWN																			
C_l'	10°				0.037		0.036		0.028		0.015		0.002	0.011	0.014	0.021	0.003		
C_n'	10°				−.002		−.006		−.006		−.003		−.002	−.004	−.004	−.008	.001		
δ_{AF}	10°				8°		7°		4°		−2°		−7°	−7°	−5°	−6°	−11°		
C_l'	20°				.056		.058		.045		.032		.015	−.013	*−.003	*−.009	*−.004		
C_n'	20°				−.003		−.010		−.010		−.008		−.007	−.006	*.002	*.002	*.004		
δ_{AF}	20°				15°		12°		8°		3°		−1°	−3°	−15°	−21°	−23°		
C_l'	30°				.075		.079		.066		.049		.026	−.015	*−.004	*−.009	*−.005		
C_n'	30°				−.004		−.014		−.014		−.012		−.010	−.007	*.003	*.003	*.005		
δ_{AF}	30°				25°		23°		18°		13°		6°	3°	−15°	−22°	−23°		
C_l'	40°				.095		.093		.086		.064		.034	−.015	−.004	−.008	.001		
C_n'	40°				−.005		−.015		−.018		−.015		−.011	−.007	.003	.002	0		
δ_{AF}	40°				36°		32°		29°		22°		12°	6°					
C_l'	50°				.112		.106		.094		.074		.039	.021	.005	.003	.013		
C_n'	50°				−.005		−.017		−.018		−.016		−.010	−.007	−.002	−.004	−.005		
δ_{AF}	50°				47°		41°		37°		29°		16°	4°					

* Ailerons fluctuate ±1° to ±2° under these conditions.

TABLE VII

FORCE TESTS. 10 BY 60 IN. CLARK Y WING WITH AILERONS 15 PER CENT c BY 60 PER CENT $b/2$
YAW = −20° R. N.=609,000 VELOCITY=80 M. P. H.

α		−10°	−5°	−3°	0°	5°	10°	12°	14°	16°	17°	18°	20°	22°	25°	30°	40°	50°	60°
	δ_A	AILERONS LOCKED—NEUTRAL																	
C_L	0°	−0.318	−0.013	0.115	0.306	0.614	0.909	1.010	1.072	1.121	1.133	1.136	1.020	0.945	0.875	0.859	0.777	0.715	0.592
C_D	0°	.048	.018	.016	.020	.039	.074	.091	.103	.128	.142	.159	.182	.335	.403	.503	.663	.851	1.032
C_l'	0°	.0	−.004	−.005	−.006	−.007	−.011	−.012	−.020	−.029	−.039	−.050	−.075	−.098	−.094	−.079	−.055	−.048	−.044
C_n'	0°	.001	.004	.003	.003	.005	.007	.009	.009	.012	.013	.015	.017	.025	.037	.047	.044	.049	.060
RIGHT AILERON UP. LEFT AILERON DOWN																			
C_l'	10°	-----	-----	-----	0.031	-----	0.030	-----	0.029	-----	0.028	-----	0.014	0.017	0.013	0.007	0.014	-----	-----
C_n'	10°	-----	-----	-----	−.004	-----	−.009	-----	−.009	-----	−.009	-----	−.010	−.014	−.012	−.009	−.008	-----	-----
C_l'	20°	-----	-----	-----	.055	-----	.057	-----	.058	-----	.057	-----	.049	.048	.028	.020	.015	-----	-----
C_n'	20°	-----	-----	-----	−.006	-----	−.015	-----	−.016	-----	−.017	-----	−.018	−.026	−.032	−.022	−.018	-----	-----
C_l'	30°	-----	-----	-----	.070	-----	.068	-----	.069	-----	.066	-----	.059	.045	.039	.032	.034	-----	-----
C_n'	30°	-----	-----	-----	−.006	-----	−.016	-----	−.019	-----	−.019	-----	−.023	−.029	−.037	−.030	−.026	-----	-----
C_l'	40°	-----	-----	-----	.087	-----	.082	-----	.083	-----	.079	-----	.070	.051	.047	.033	.020	-----	-----
C_n'	40°	-----	-----	-----	−.008	-----	−.020	-----	−.022	-----	−.023	-----	−.026	−.033	−.041	−.033	−.024	-----	-----
C_l'	50°	-----	-----	-----	.097	-----	.095	-----	.091	-----	.092	-----	.081	.079	.055	.036	.014	-----	-----
C_n'	50°	-----	-----	-----	−.008	-----	−.020	-----	−.023	-----	−.025	-----	−.029	−.033	−.046	−.037	−.024	-----	-----
LEFT AILERON DOWN. RIGHT AILERON 0°																			
C_l'	10°	-----	-----	-----	0.011	-----	0.012	-----	0.008	-----	0.009	-----	0.008	0.005	0.005	0.003	0.003	-----	-----
C_n'	10°	-----	-----	-----	−.003	-----	−.005	-----	−.003	-----	−.003	-----	−.003	−.005	−.004	−.006	−.005	-----	-----
C_l'	20°	-----	-----	-----	.018	-----	.020	-----	.020	-----	.017	-----	.012	.007	.009	.005	.004	-----	-----
C_n'	20°	-----	-----	-----	−.005	-----	−.008	-----	−.007	-----	−.006	-----	−.007	−.008	−.008	−.008	−.008	-----	-----
C_l'	30°	-----	-----	-----	.026	-----	.024	-----	.027	-----	.022	-----	.015	.010	.011	.006	.004	-----	-----
C_n'	30°	-----	-----	-----	−.008	-----	−.011	-----	−.011	-----	−.010	-----	−.011	−.012	−.013	−.011	−.011	-----	-----
C_l'	40°	-----	-----	-----	.034	-----	.029	-----	.029	-----	.027	-----	.018	.012	.015	.008	.005	-----	-----
C_n'	40°	-----	-----	-----	−.011	-----	−.015	-----	−.014	-----	−.013	-----	−.015	−.015	−.015	−.014	−.015	-----	-----
RIGHT AILERON UP. LEFT AILERON 0°																			
C_l'	10°	-----	-----	-----	0.019	-----	0.017	-----	0.018	-----	0.018	-----	0.019	0.013	0.011	0.003	0.006	-----	-----
C_n'	10°	-----	-----	-----	−.003	-----	−.005	-----	−.005	-----	−.005	-----	−.006	−.008	−.006	−.005	−.005	-----	-----
C_l'	20°	-----	-----	-----	.034	-----	.032	-----	.034	-----	.036	-----	.036	.023	.022	.014	.012	-----	-----
C_n'	20°	-----	-----	-----	−.002	-----	−.007	-----	−.007	-----	−.009	-----	−.011	−.014	−.014	−.012	−.102	-----	-----
C_l'	30°	-----	-----	-----	.044	-----	.041	-----	.040	-----	.039	-----	.040	.031	.029	.022	.022	-----	-----
C_n'	30°	-----	-----	-----	0	-----	−.006	-----	−.007	-----	−.008	-----	−.011	−.025	−.015	−.016	−.014	-----	-----
C_l'	40°	-----	-----	-----	.054	-----	.051	-----	.049	-----	.048	-----	.049	.053	.032	.022	.013	-----	-----
C_n'	40°	-----	-----	-----	.003	-----	−.005	-----	−.007	-----	−.008	-----	−.011	−.014	−.035	−.015	−.008	-----	-----
C_l'	60°	-----	-----	-----	.062	-----	.065	-----	.062	-----	.062	-----	.062	.065	.043	.025	.008	-----	-----
C_n'	60°	-----	-----	-----	.008	-----	−.001	-----	−.004	-----	−.006	-----	−.008	−.011	−.023	−.016	−.007	-----	-----
C_l'	80°	-----	-----	-----	.067	-----	.068	-----	.068	-----	.067	-----	.067	.070	.046	.026	.007	-----	-----
C_n'	80°	-----	-----	-----	.013	-----	.002	-----	0	-----	−.003	-----	−.006	−.008	−.021	−.015	−.007	-----	-----
AILERONS FLOATING—NEUTRAL																			
C_L	0°	−0.337	−0.046	0.078	0.262	0.574	0.863	0.960	1.012	1.024	1.025	1.020	1.015	0.850	0.790	0.755	0.672	0.621	0.495
C_D	0°	.049	.017	.016	.018	.035	.065	.080	.093	.110	.118	.131	.170	.286	.341	.444	.583	.764	.897
C_l'	0°	0	−.003	−.005	−.004	−.008	−.009	−.012	−.016	−.027	−.032	−.040	−.054	−.083	−.100	−.080	−.055	−.045	−.036
C_n'	0°	.003	.002	.001	.001	.002	.004	.006	.008	.010	.011	.011	.011	.012	.029	.039	.045	.050	.053
δ_{AF}	0°	−2°	−3°	−4°	−5°	−4°	−6°	−7°	−9°	−10°	−14°	−16°	−19°	−19°	−19°	−23°	−27°	−30°	−34°
RIGHT AILERON UP. LEFT AILERON DOWN																			
C_l'	10°	-----	-----	-----	0.030	-----	0.029	-----	0.029	-----	0.022	-----	0.012	0.011	0.019	0.014	0.014	-----	-----
C_n'	10°	-----	-----	-----	−.001	-----	−.005	-----	−.006	-----	−.005	-----	−.002	−.002	−.002	−.003	−.008	-----	-----
δ_{AF}	10°	-----	-----	-----	11°	-----	6°	-----	3°	-----	0°	-----	−5°	−5°	−5°	−10°	−10°	-----	-----
C_l'	20°	-----	-----	-----	.047	-----	.049	-----	.042	-----	.037	-----	.025	.034	.028	[a] .018	[b] −.004	-----	-----
C_n'	20°	-----	-----	-----	−.002	-----	−.008	-----	−.009	-----	−.008	-----	−.006	−.004	−.006	[a] −.008	[b] −.004	-----	-----
δ_{AF}	20°	-----	-----	-----	18°	-----	13°	-----	11°	-----	8°	-----	5°	5°	4°	2°	−13°	-----	-----
C_l'	30°	-----	-----	-----	.066	-----	.067	-----	.065	-----	.056	-----	.071	.047	.038	[a] .022	[a] −.003	-----	-----
C_n'	30°	-----	-----	-----	−.003	-----	−.011	-----	−.014	-----	−.012	-----	−.010	−.009	−.021	[a] −.009	[a] .002	-----	-----
δ_{AF}	30°	-----	-----	-----	27°	-----	25°	-----	22°	-----	18°	-----	17°	16°	19°	7°	−24°	-----	-----
C_l'	40°	-----	-----	-----	.081	-----	.080	-----	.079	-----	.071	-----	.053	.057	.045	.027	−.002	-----	-----
C_n'	40°	-----	-----	-----	−.004	-----	−.013	-----	−.017	-----	−.016	-----	−.014	−.013	−.026	−.012	−.001	-----	-----
δ_{AF}	40°	-----	-----	-----	37°	-----	33°	-----	35°	-----	32°	-----	30°	29°	31°	14°	−16°	-----	-----
C_l'	50°	-----	-----	-----	.093	-----	.092	-----	.088	-----	.083	-----	.063	.067	.053	[a] .029	.008	-----	-----
C_n'	50°	-----	-----	-----	−.004	-----	−.015	-----	−.019	-----	−.018	-----	−.016	−.015	−.031	[a] −.014	−.010	-----	-----
δ_{FA}	50°	-----	-----	-----	50°	-----	46°	-----	44°	-----	43°	-----	40°	40°	45°	20°	-----	-----	-----

[a] Ailerons fluctuate ±1° to ±2° under these conditions.

[b] Ailerons fluctuate ±3° to ±4° under these conditions.

TABLE VIII

ROTATION TESTS. 10 BY 60 IN. CLARK Y WING WITH PLAIN AILERONS 15 PER CENT c BY 60 PER CENT $b/2$

C_λ is given for forced rotation at $\frac{p'b}{2V}=0.05\begin{cases}(+)\text{ aiding rotation}\\(-)\text{ damping rotation}\end{cases}$

$\frac{p'b}{2V}$ values are for free rotation

Yaw=0°. Velocity=80 m. p. h. R. N.=609,000

	α	0°	12°	14°	16°	18°	19°	20°	22°	24°	25°	26°	28°	29°	30°	32°	35°	38°	40°
AILERONS LOCKED—NEUTRAL																			
(+) Rotation (clockwise)	C_λ	−0.0203	−0.0182	−0.0148	−0.0056	0.0032		0.0242	0.0264		0.0026				0.0097				−0.0018
	$\frac{p'b}{2V}$					.294		.320	.335	0.350	.361	0.367	0.378		.390	0.311			
(−) Rotation (counterclockwise)	C_λ	−.0216	−.0170	−.0160	−.0050	.0032		.0280	.0215		−.0125				−.0027				−.0005
	$\frac{p'b}{2V}$					.290		.312	.337	.355	*.361						*0.063	*0.065	
AILERONS FLOATING—NEUTRAL																			
(+) Rotation (clockwise)	C_λ	−0.0213	−0.0210	−0.0174	−0.0131	−0.0068		0.0102	0.0240		0.0048				0.0008				−0.0041
	$\frac{p'b}{2V}$							.299	.310		.331	0.338	0.088		.092	0.073			
(−) Rotation (counterclockwise)	C_λ	−.0200	−.0184	−.0153	−.0100	−.0045		.0190	.0240		.0065				−.0036				−.0002
	$\frac{p'b}{2V}$						0.287	.299	.317		.347	*.349							

* Not self-starting.

TABLE IX

ROTATION TESTS. 10 IN. BY 60 IN. CLARK Y WING WITH PLAIN AILERONS 15 PER CENT c BY 60 PER CENT $b/2$

C_λ is given for forced rotation at $\frac{p'b}{2V}=0.05\begin{cases}(+)\text{ aiding rotation}\\(-)\text{ damping rotation}\end{cases}$

Yaw=−20° Velocity=80 m. p. h. R. N.=609,000

	α	0°	12°	14°	16°	18°	19°	20°	22°	23°	25°	26°	28°	29°	30°	32°	35°	38°	40°
AILERONS LOCKED—NEUTRAL																			
(−) Rotation (counterclockwise)	C_λ	−0.0173	0.0036	0.0122	0.0247	0.0438		0.0822	0.0847		0.0871				0.0772				0.0464
(+) Rotation (clockwise)	C_λ	.0275	.0375	.0430	.0525	.0672		.0718	.0800		.0868				.0705				.0535
AILERONS FLOATING—NEUTRAL																			
(−) Rotation (counterclockwise)	C_λ	−0.0138	−0.0018	0.0044	0.0140	0.0282		0.0662	0.0762		0.0798				0.0723				0.0440
(+) Rotation (clockwise)	C_λ	.0245	.0330	.0355	.0415	.0515		.0620	.0733		.0788				.0690				.0408

TABLE X

FORCE TESTS. 10 BY 60 IN. CLARK Y WING WITH PLAIN AILERONS 40 PER CENT c BY 30 PER CENT $b/2$
YAW=0° R. N.=609,000 VELOCITY=80 M. P. H.

α	δ_A	−10°	−5°	−3°	0°	5°	10°	12°	14°	15°	17°	18°	20°	22°	25°	30°	40°	50°	60°
AILERONS LOCKED—NEUTRAL																			
C_L	0°	−0.316	−0.003	0.140	0.350	0.714	1.043	1.152	1.225	1.252	1.230	1.210	1.070	0.805	0.783	0.850	0.790	0.698	0.585
C_D	0°	.075	.017	.016	.021	.046	.087	.105	.125	.139	.173	.196	.290	.353	.411	.536	.713	.868	1.035
RIGHT AILERON UP. LEFT AILERON DOWN																			
C_l'	10°				0.031		0.035		0.032		0.022		0.015	0.005	0.002	0.004	0		
C_n'	10°				−.003		−.010		−.013		−.014		−.014	−.013	−.010	−.008	−.008		
C_l'	20°				.070		.067		.062		.052		.032	.016	.003	.006	.005		
C_n'	20°				−.007		−.019		−.022		−.025		−.023	−.021	−.017	−.015	−.017		
C_l'	30°				.086		.090		.086		.075		.052	.030	.009	.010	.009		
C_n'	30°				−.006		−.022		−.028		−.031		−.028	−.027	−.027	−.021	−.025		
C_l'	40°				.098		.102		.099		.088		.070	.042	.020	.014	.015		
C_n'	40°				−.005		−.020		−.026		−.029		−.028	−.028	−.031	−.026	−.033		
C_l'	50°				.108		.110		.108		.094		.078	.044	.028	.013	.017		
C_n'	50°				−.006		−.019		−.025		−.027		−.026	−.026	−.033	−.028	−.037		
LEFT AILERON DOWN. RIGHT AILERON 0°																			
C_l'	10°				0.018		0.014		0.014		0.007		0.002	−0.002	−0.001	0.001	0		
C_n'	10°				−.002		−.006		−.007		−.008		−.006	−.006	−.005	−.003	−.004		
C_l'	20°				.033		.028		.025		.017		.001	−.005	−.004	−.002	−.001		
C_n'	20°				−.008		−.014		−.015		−.015		−.011	−.008	−.008	−.007	−.011		
C_l'	30°				.038		.032		.028		.023		.001	−.011	−.006	−.006	−.005		
C_n'	30°				−.013		−.019		−.022		−.022		−.014	−.011	−.013	−.010	−.014		
C_l'	40°				.040		.031		.026		.019		.001	−.015	−.011	−.009	−.008		
C_n'	40°				−.017		−.023		−.025		−.024		−.018	−.015	−.016	−.015	−.018		
RIGHT AILERON UP. LEFT AILERON 0°																			
C_l'	10°				0.019		0.019		0.017		0.014		0.009	0.004	0	0.004	0.001		
C_n'	10°				0		−.004		−.005		−.005		−.006	−.007	−.005	−.004	−.003		
C_l'	20°				.037		.039		.037		.034		.029	.021	.005	.009	.006		
C_n'	20°				.002		−.005		−.007		−.009		−.012	−.013	−.009	−.007	−.008		
C_l'	30°				.048		.055		.054		.050		.048	.038	.009	.014	.012		
C_n'	30°				.007		−.002		−.006		−.009		−.013	−.015	−.011	−.009	−.011		
C_l'	40°				.058		.071		.072		.068		.066	.054	.019	.019	.020		
C_n'	40°				.012		.004		.001		−.005		−.009	−.012	−.010	−.010	−.014		
C_l'	50°				.064		.080		.083		.079		.079	.066	.035	.018	.027		
C_n'	50°				.016		.009		.005		0		−.005	−.007	−.008	−.006	−.015		
C_l'	60°				.070		.083		.087		.083		.085	.082	.042	.024	.022		
C_n'	60°				.021		.012		.008		.004		0	−.002	−.006	−.004	−.011		
C_l'	80°				.076		.092		.095		.088		.091	.077	.043	.032	.016		
C_n'	80°				.031		.020		.015		.012		.006	.004	.001	.002	−.010		
AILERONS FLOATING—NEUTRAL																			
C_L	0°	−0.377	−0.096	0.035	0.228	0.568	0.875	0.981	1.060	1.083	1.071	1.053	1.008	[a] 0.972	[a] 0.653	0.626	0.607	0.563	0.488
C_D	0°	.079	.021	.019	.020	.036	.066	.082	.097	.108	.133	.151	.186	[a] .216	[a] .330	.410	.577	.743	.892
δ_{AF}	0°	−5°	−8°	−9°	−10°	−13°	−16°	−18°	−19°	−21°	−21°	−20°	−21°	−22°	−30°	−42°	−44°	−50°	−52°
RIGHT AILERON UP. LEFT AILERON DOWN																			
C_l'	10°				0.037		0.039		0.038		0.040		0.030	0.037	[b] 0.016	0.007	0.14		
C_n'	10°				.002		−.001		−.003		−.004		−.006	−.007	[b] −.003	.002	−.003		
δ_{AF}	10°				0°		−6°		−9°		−11°		−13°	−31°	−19°	−32°	−31°		
C_l'	20°				.073		.074		.071		.064		.059	.058	[a] .028	[a] .013	.002		
C_n'	20°				−.002		−.005		−.008		−.010		−.012	−.012	−.001	.002	.002		
δ_{AF}	20°				15°		8°		5°		5°		2°	0°	−3°	−18°	−38°		
C_l'	30°				.091		.101		.101		.085		.073	.062	[a] .041	[a] .026	[b] .011		
C_n'	30°				.002		−.006		−.010		−.015		−.017	−.017	[a] −.009	[a] −.003	[b] −.002		
δ_{AF}	30°				22°		17°		17°		15°		15°	16°	13°	−1°	−20°		
C_l'	40°				.103		.114		.116		.106		.079	.064	[a] .046	.034	.013		
C_n'	40°				.005		−.006		−.011		−.017		−.019	−.019	[a] −.014	−.009	−.007		
δ_{AF}	40°				28°		24°		23°		24°		27°	28°	25°	13°	−2°		
C_l'	50°				.111		.122		.121		.108		.082	.062	[a] .045	[a] .036	.014		
C_n'	50°				.002		−.006		−.011		−.016		−.020	−.020	[a] −.016	[a] −.012	−.016		
δ_{AF}	50°				41°		32°		31°		32°		40°	42°	39°	25°	18°		

[a] Ailerons fluctuate ±1° to ±2° under these conditions.

[b] Ailerons fluctuate ±3° to±4° under these conditions.

TABLE XI

FORCE TESTS. 10 BY 60 IN. CLARK Y WING WITH AILERONS 40 PER CENT *c* BY 30 PER CENT *b*/2
YAW=−20° R. N.=609,000 VELOCITY=80 M. P. H.

α		−10°	−5°	−3°	0°	5°	10°	12°	14°	15°	17°	18°	20°	22°	25°	30°	40°	50°	60°
	δ_A	AILERONS LOCKED—NEUTRAL																	
C_L	0°	−0.307	−0.005	0.126	0.313	0.645	0.939	1.030	1.102	1.125	1.155	1.160	1.160	0.917	0.888	0.873	0.787	0.736	0.017
C_D	0°	.033	.019	.018	.022	.042	.080	.096	.113	.122	.146	.164	.209	.345	.411	.503	.664	.851	1.014
C_l'	0°	−.001	−.005	−.006	−.008	−.010	−.015	−.018	−.024	−.029	−.040	−.048	−.063	−.093	−.103	−.090	−.056	−.048	−.044
C_n'	0°	.003	.002	.002	.002	.003	.006	.007	.009	.012	.015	.017	.021	.030	.039	.051	.044	.049	.058
RIGHT AILERON UP. LEFT AILERON DOWN																			
C_l'	10°	------	------	------	0.035	------	0.025	------	0.031	------	0.028	------	0.023	0.010	0.015	0.007	0.002	------	------
C_n'	10°	------	------	------	−.003	------	−.009	------	−.012	------	−.012	------	−.014	−.017	−.015	−.013	−.010	------	------
C_l'	20°	------	------	------	.068	------	.069	------	.065	------	.059	------	.032	.030	.033	.019	.002	------	------
C_n'	20°	------	------	------	−.005	------	−.020	------	−.024	------	−.024	------	−.025	−.033	−.033	−.029	−.017	------	------
C_l'	30°	------	------	------	.102	------	.103	------	.098	------	.088	------	.076	.069	.053	.038	.005	------	------
C_n'	30°	------	------	------	−.008	------	−.032	------	−.039	------	−.034	------	−.034	−.042	−.045	−.043	−.026	------	------
C_l'	40°	------	------	------	.106	------	.114	------	.116	------	.115	------	.102	.090	.069	.056	.010	------	------
C_n'	40°	------	------	------	−.004	------	−.026	------	−.037	------	−.038	------	−.037	−.047	−.051	−.052	−.063	------	------
C_l'	50°	------	------	------	.110	------	.121	------	.133	------	.134	------	.126	.113	.088	.073	.017	------	------
C_n'	50°	------	------	------	−.004	------	−.019	------	−.033	------	−.036	------	−.036	−.045	−.051	−.055	−.043	------	------
LEFT AILERON DOWN. RIGHT AILERON 0°																			
C_l'	10°	------	------	------	0.016	------	0.015	------	0.014	------	0.011	------	0.007	−0.006	0.003	0.002	0.001	------	------
C_n'	10°	------	------	------	−.002	------	−.004	------	−.006	------	−.005	------	−.005	−.006	−.004	−.004	−.005	------	------
C_l'	20°	------	------	------	.032	------	.034	------	.030	------	.022	------	.014	−.003	.005	−.002	.002	------	------
C_n'	20°	------	------	------	−.007	------	−.014	------	−.016	------	−.012	------	−.012	−.012	−.008	−.009	−.009	------	------
C_l'	30°	------	------	------	.046	------	.049	------	.044	------	.031	------	.018	−.002	.006	−.001	0	------	------
C_n'	30°	------	------	------	−.016	------	−.028	------	−.030	------	−.021	------	−.017	−.017	−.014	−.012	−.012	------	------
C_l'	40°	------	------	------	.040	------	.038	------	.051	------	.034	------	.019	−.002	.005	−.003	−.003	------	------
C_n'	40°	------	------	------	−.018	------	−.028	------	−.043	------	−.028	------	−.023	−.029	−.014	−.017	−.015	------	------
RIGHT AILERON UP. LEFT AILERON 0°																			
C_l'	10°	------	------	------	0.018	------	0.018	------	0.017	------	0.017	------	0.016	0.005	0.009	0.001	0.001	------	------
C_n'	10°	------	------	------	0	------	−.004	------	−.006	------	−.007	------	−.009	−.013	−.011	−.007	−.005	------	------
C_l'	20°	------	------	------	.036	------	.036	------	.036	------	.039	------	.036	.023	.027	.015	0	------	------
C_n'	20°	------	------	------	.002	------	−.005	------	−.009	------	−.011	------	−.015	−.023	−.021	−.019	−.008	------	------
C_l'	30°	------	------	------	.058	------	.054	------	.053	------	.054	------	.056	.040	.044	.032	.006	------	------
C_n'	30°	------	------	------	.008	------	−.004	------	−.008	------	−.011	------	−.017	−.034	−.028	−.027	−.013	------	------
C_l'	40°	------	------	------	.066	------	.078	------	.077	------	.079	------	.077	.076	.061	.051	.013	------	------
C_n'	40°	------	------	------	.015	------	.003	------	−.004	------	−.008	------	−.015	−.024	−.030	−.032	−.017	------	------
C_l'	50°	------	------	------	.066	------	.099	------	.098	------	.099	------	.102	.101	.082	.072	.024	------	------
C_n'	50°	------	------	------	.018	------	.013	------	.005	------	0	------	−.008	−.018	−.026	−.032	−.019	------	------
C_l'	60°	------	------	------	.069	------	.092	------	.115	------	.117	------	.118	.119	.099	.091	.039	------	------
C_n'	60°	------	------	------	.021	------	.016	------	.016	------	.010	------	.001	−.010	−.019	−.028	−.021	------	------
C_l'	80°	------	------	------	.072	------	.092	------	.102	------	.111	------	.119	.120	.094	.082	.048	------	------
C_n'	80°	------	------	------	.030	------	.020	------	.017	------	.016	------	.009	−.001	−.011	−.021	−.012	------	------
AILERONS FLOATING—NEUTRAL																			
C_L	0°	−0.338	−0.074	0.041	0.208	0.503	0.774	0.870	0.944	0.973	1.018	1.016	[a]0.900	[a]0.840	0.725	0.734	[b]0.688	[a]0.610	[a]0.500
C_D	0°	.035	.020	.019	.021	.036	.062	.074	.089	.096	.116	.130	[a].231	[a].261	.331	.418	[b].503	[a].730	[a].890
C_l'	0°	0	−.003	−.004	−.006	−.007	−.010	−.012	−.017	−.020	−.027	−.034	[a]−.049	[a]−.051	−.055	−.061	[b]−.050	[a]−.035	[a]−.034
C_n'	0°	.002	.002	.001	.001	.002	.003	.005	.006	.007	.009	.021	[a].012	[a].015	.023	.029	[b].039	[a].041	[a].048
δ_{AF}	0°	−3°	−6°	−7°	−10°	−15°	−20°	−22°	−22°	−24°	−25°	−25°	−30°	−35°	−38°	−40°	−60°	−65°	−65°
RIGHT AILERON UP. LEFT AILERON DOWN																			
C_l'	10°	------	------	------	0.034	------	0.035	------	0.033	------	0.029	------	0.027	0.006	0.006	[b]0.009	0.005	------	------
C_n'	10°	------	------	------	.001	------	−.001	------	−.002	------	−.003	------	−.004	−.012	−.002	[b]−.002	−.001	------	------
δ_{AF}	10°	------	------	------	2°	------	−7°	------	−10°	------	−11°	------	−13°	−18°	−15°	−18°	−35°	------	------
C_l'	20°	------	------	------	.070	------	.063	------	.066	------	.059	------	.049	.036	.020	.026	[a].017	------	------
C_n'	20°	------	------	------	0	------	−.004	------	−.006	------	−.007	------	−.008	.010	−.007	−.009	[a]−.005	------	------
δ_{AF}	20°	------	------	------	18°	------	10°	------	7°	------	5°	------	1°	0°	−1°	−4°	−17°	------	------
C_l'	30°	------	------	------	.106	------	.109	------	.103	------	.092	------	.076	.060	.035	.042	[a].032	------	------
C_n'	30°	------	------	------	−.001	------	−.007	------	−.010	------	−.012	------	−.014	−.016	−.014	−.017	[a]−.015	------	------
δ_{AF}	30°	------	------	------	29°	------	20°	------	19°	------	20°	------	18°	16°	15°	13°	0°	------	------
C_l'	40°	------	------	------	.103	------	.144	------	.140	------	.122	------	.098	.077	.047	.053	.043	------	------
C_n'	40°	------	------	------	.002	------	−.008	------	−.011	------	−.015	------	−.019	−.022	−.020	−.025	−.023	------	------
δ_{AF}	40°	------	------	------	36°	------	30°	------	26°	------	27°	------	28°	29°	30°	26°	18°	------	------
C_l'	50°	------	------	------	.107	------	.126	------	.148	------	.143	------	.112	.086	.055	.060	[a].045	------	------
C_n'	50°	------	------	------	.002	------	−.007	------	−.016	------	−.015	------	−.021	−.025	−.025	−.031	[a]−.027	------	------
δ_{AF}	50°	------	------	------	43°	------	32°	------	32°	------	40°	------	43°	42°	41°	40°	28°	------	------

[a] Ailerons fluctuate ±1° to ±2° under these conditions.

[b] Ailerons fluctuate ±3° to ±4° under these conditions.

TABLE XII

ROTATION TESTS. 10 BY 60 IN. CLARK Y WING WITH PLAIN AILERONS 40 PER CENT c BY 30 PER CENT $b/2$

C_λ is given for forced rotation at $\frac{p'b}{2V}=0.05\begin{cases}(+)\text{ aiding rotation}\\(-)\text{ damping rotation}\end{cases}$

$\frac{p'b}{2V}$ values are for free rotation.

Yaw=0° Velocity=80 m. p. h. R. N.=609,000

	α	0°	12°	14°	16°	17°	18°	19°	20°	21°	22°	23°	25°	26°	27°	28°	29°	30°	40°
AILERONS LOCKED—NEUTRAL																			
(+) Rotation (clockwise)	C_λ	−0.0223	−0.0210	−0.0143	0.0010	------	0.0144	0.0217	0.0220	0.0147	0.0067	----	−0.0148	----	------	------	------	−0.0068	−0.0016
	$\frac{p'b}{2V}$	------	------	------	------	[a]0.264	.311	------	.334	.349	.361	----	.378	----	0.374	0.408	[a]0.408	------	------
(−) Rotation (counter-clockwise)	C_λ	−.0222	−.0203	−.0124	−.0043	------	.0012	.0075	.0200	.0200	.0200	----	.0190	----	------	------	------	.0170	.0065
	$\frac{p'b}{2V}$	------	------	------	------	[a].258	.321	------	.334	.338	.361	----	.374	----	.378	.408	[a].415	------	------
AILERONS FLOATING—NEUTRAL																			
(+) Rotation (clockwise)	C_λ	−0.0231	−0.0236	−0.0210	−0.0098	------	−0.0023	0.0044	0.0062	−0.0023	−0.0049	----	−0.0042	----	------	------	------	0.0006	−0.0046
	$\frac{p'b}{2V}$	------	------	------	------	------	------	.138	.136	[a].100	------	----	------	----	------	0.065	------	.070	------
(−) Rotation (counter-clockwise)	C_λ	−.0180	−.0192	−.0158	−.0092	------	.0010	−.0026	.0082	.0030	−.0034	----	−.0020	----	------	------	------	.0020	−.0030
	$\frac{p'b}{2V}$	------	------	------	------	------	------	.140	.130	[a].108	------	----	------	----	------	.052	------	.062	------

[a] Not self-starting.

TABLE XIII

ROTATION TESTS. 10 IN. BY 60 IN. CLARK Y WING WITH PLAIN AILERONS 40 PER CENT c BY 30 PER CENT $b/2$

C_λ is given for forced rotation at $\frac{p'b}{2V}=0.05\begin{cases}(+)\text{ aiding rotation}\\(-)\text{ damping rotation}\end{cases}$

Yaw=−20° Velocity=80 m. p. h. R. N.=609,000

	α	0°	12°	14°	16°	18°	19°	20°	22°	23°	25°	26°	28°	29°	30°	32°	35°	38°	40°
AILERONS LOCKED—NEUTRAL																			
(−) Rotation (counterclockwise)	C_λ	−0.0152	0.0012	0.0084	0.0220	0.0408	----	0.0798	0.0847	----	0.0822	----	----	----	0.0724	----	----	----	0.0453
(+) Rotation (clockwise)	C_λ	−.0262	−.0352	−.0391	−.0486	−.0625	----	−.0668	−.0802	----	−.0820	----	----	----	−.0707	----	----	----	−.0526
AILERONS FLOATING—NEUTRAL																			
(−) Rotation (counterclockwise)	C_λ	−0.0170	−0.0058	−0.0020	0.0042	0.0162	----	0.0392	0.0410	----	0.0440	----	----	----	0.0468	----	----	----	0.0402
(+) Rotation (clockwise)	C_λ	−.0226	−.0312	−.0336	−.0398	−.0514	----	−.0586	.0560	----	−.0532	----	----	----	−.0566	----	----	----	−.0438

TABLE XIV

CRITERIONS SHOWING RELATIVE MERIT OF AILERONS

Subject	Criterion	Plain ailerons 15 per cent chord by 60 per cent semispan					Plain ailerons 25 per cent chord by 40 per cent semispan (assumed standard size)					Plain ailerons 40 per cent chord by 30 per cent semispan				
		Standard, 25° up, 25° down	Differential, No. 1, 35° up, 15° down	Differential, No. 2, 50° up, 7° down	Up only, 60°	Floating, 50° difference	Standard, 25° up, 25° down	Differential, No. 1, 35° up, 15° down	Differential, No. 2, 50° up, 7° down	Up only, 60°	Floating, 50° difference	Standard, 25° up, 25° down	Differential, No. 1, 35° up, 15° down	Differential, No. 2, 50° up, 7° down	Up only, 60°	Floating, 50° difference
Wing area or minimum speed.	Maximum C_L ($\delta_A=0°$)	1.222	1.222	1.222	1.222	1.140	1.270	1.270	1.270	1.270	1.163	1.258	1.258	1.258	1.258	1.083
Speed range	Max C_L/Min C_D ($\delta_A=0°$)	76.4	76.4	76.4	76.4	76.0	79.4	79.4	79.4	79.4	77.8	78.5	78.5	78.5	78.5	57.0
Rate of climb	L/D at C_L=0.70 ($\delta_A=0°$)	15.9	15.9	15.9	15.9	16.3	15.9	15.9	15.9	15.9	16.3	15.9	15.9	15.9	15.9	14.9
Lateral controllability.	RC $\alpha=0°$	.218	.233	.233	.203	.230	.204	.202	.214	.196	.243	.226	.234	.226	.202	.300
	RC $\alpha=10°$	.071	.071	.075	.064	.073	.076	.074	.074	.072	.083	.078	.084	.083	.076	.101
	RC $\alpha=20°$	.020	.018	.032	.029	.021	.038	.051	.055	.054	.035	.046	.053	[g].073	[h].074	.008
	RC $\alpha=30°$	.054	.027	.013	.009	−.015	.017	.005	.002	.002	−.018	.019	.025	.026	.022	.025
Lateral control with sideslip.	Maximum α at which ailerons will balance C_l' due to 20° yaw.	19°	18°	19°	19°	18°	20°	20°	21°	22°	19°	19°	20°	22°	25°	24°
Yawing moment due to ailerons, (+) favorable (−) unfavorable.	C_n $\alpha=0°$	------	------	.005	.010	------	------	.002	.010	.016	------	------	.005	.016	.021	[e].002
		−.006	[b]−.003	[b]−.003	[a]−.001	−.003	−.007	[b]−.003	[b]−.002	------	−.002	−.007	[b]−.002	[a]−.001	------	------
	C_n $\alpha=10°$	------	.002	.009	.012	------	------	.004	.013	.018	.002	------	.006	.020	.026	.009
		−.003	[a]−.002	[a]−.001	[a]−.001	------	−.004	[b]−.002	[b]−.001	------	------	−.007	[b]−.003	[a]−.002	------	------
	C_n $\alpha=20°$	------	------	------	.003	------	------	------	.008	.013	------	------	.001	.019	.029	.010
		−.012	[a]−.009	[a]−.008	[a]−.004	[b]−.002	−.010	[b]−.007	[b]−.006	[a]−.003	−.002	−.010	[b]−.008	[b]−.007	[a]−.003	------
	C_n $\alpha=30°$	------	[d].001	------	[d].003	[e].004	------	------	------	.002	.002	------	------	.003	.009	.009
		[a]−.002	[a]−.002	−.002	−.001	[f]−.003	−.008	−.008	[b]−.007	[b]−.004	[f]−.003	−.012	[d]−.009	[a]−.005	[a]−.002	------
Lateral stability ($\delta_A=0°$).	α for initial instability in rolling.	18°	18°	18°	18°	19°	18°	18°	18°	18°	21°	18°	18°	18°	18°	19°
	α for initial instability at $\frac{p'b}{2V}$=0.05 Yaw=0°.	17°	17°	17°	17°	19°	17°	17°	17°	17°	21°	17°	17°	17°	17°	18°
	α for initial instability at $\frac{p'b}{2V}$=0.05 Yaw=20°.	10°	10°	10°	10°	13°	11°	11°	11°	11°	15°	12°	12°	12°	12°	15°
	Maximum unstable C_λ. Yaw=0°.	.028	.028	.028	.028	.024	.048	.048	.048	.048	.016	.022	.022	.022	.022	.008
	Maximum unstable C_λ. Yaw=20°.	.087	.087	.087	.087	.080	.093	.093	.093	.093	.071	.085	.085	.085	.085	.047
Control force required.	CF $\alpha=0°$	.010	.012	.015	.021	.012	.017	.019	.028	.041	.022	.030	.032	.052	.070	.046
	CF $\alpha=10°$	.003	.002	.003	.006	.004	.006	.005	.005	.010	.007	.010	.007	.007	.014	.012
	CF $\alpha=20°$	.003	.002	------	------	------	.006	.003	------	------	------	.009	.004	------	------	------
	CF $\alpha=30°$	.003	.002	------	------	------	.007	.003	------	------	------	.011	.004	------	------	------

[a] to [f] Where the maximum yawing moment occurred below maximum deflection, the letters indicate the deflection of the up aileron as follows: [a]=10°, [b]=15°, [c]=20°, [d]=25°, [e]=30°, [f]=40°.

[g] RC has a minimum value of 0.066 at $\alpha=17°$ and a maximum of 0.079 at $\alpha=22°$.

[h] RC=0.064 at $\alpha=17°$ and 0.094 at $\alpha=22°$.